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APPLICATION OF ERTS-1 DATA TO THE PROTECTION AND MANAGEMENT OF NEW JERSEY'S COASTAL ENVIRONMENT

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16. Abstract

Quasi-operational information products for coastal zone management have been prepared using ERTS-1 imagery and collateral aerial photography. These products were applied to the practical regulation, protection, and management of New Jersey's coastal environment. Procedures were developed for the operational use of ERTS-1 data products within New Jersey's Department of Environmental Protection. Successful analysis and product preparation for operational needs centered on four major coastal resource problem areas; detection of environmental changes in coastal areas; siting of ocean outfalls; monitoring of offshore waste disposal; and calculation of recession rates along the Atlantic Shore. The utility and monetary benefits derived from ERTS and aircraft imagery for each problem area have been determined. The NJDEP estimates the possibility of $620,000 yearly savings through the use of an operational ERTS system and a one-time savings of $2.8 million on current or planned projects if a truly operational ERTS type satellite were available.

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PREFACE

The principal thrust of this ERTS-1 experiment was to develop quasi-operational information products from analysis of ERTS-1 imagery and collateral aerial photography and to apply these products to the practical regulation, protection and management of New Jersey's coastal environment. Incorporated into this goal was the development of procedures for the operational use of ERTS-1 data products within New Jersey's Department of Environmental Protection. These goals have been met. Analysis and product preparation for operational needs centered on four major coastal resource problem areas: detection of land-use changes in the coastal zone; siting of ocean outfalls; monitoring of offshore waste disposal; and calculation of recession rates along the Atlantic Shore. The relative utility and estimated monetary benefits derived from ERTS and aircraft imagery for each problem area was determined. Of equal importance was the development of a capability within the State to use and understand remote sensor-derived information, and the application of this information to meet the requirements of current and anticipated coastal zone legislation.

ERTS data has increased efficiency within the State in several areas; many ERTS-derived products have been evaluated and have been found to be either of yearly or one-time value, whereas other ERTS products have provided necessary repetitive information needs. For operational needs, ERTS data, on its own, has proven or appears to have the greatest value in (1) land use change detection, (2) waterfowl game management, (3) offshore waste disposal, and (4) floodplains mapping. Greatest overall benefit to the State has accrued from analysis of ERTS-1 data coupled with a well coordinated aircraft and ground data collection system. Problems of shore erosion and siting of ocean outfalls were most efficiently investigated through this approach.

For the resolution of specific coastal resource problems, the results of this investigation indicate that ERTS overpasses coupled with repetitive aircraft coverage can be productive and cost effective. The success of this ERTS investigation in addressing these coastal resource problems has convinced the State of New Jersey to include in its next budget fifty thousand dollars ($50,000) to participate in the kinds of activities addressed during this investigation.

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EPA defines the release zone as "the area swept out by the locus of points constantly 100 meters from the perimeter of the conveyance engaged in dumping activities, beginning at the first moment in which dumping is scheduled to occur and ending at the last moment in which dumping is scheduled to occur." The mixing zone is defined as "the column of water immediately contiguous to the release zone, beginning at the surface of the water and ending at the ocean floor, the thermocline or halocline, if one exists, or 20 meters, whichever is the shortest distance." No definition is made of the lateral confines of the mixing zone except the wording immediately contiguous to the release zone. The rather large geographical extent of the dumps shown in Figure 21 probably does not fit the definition of an immediately contiguous mixing zone to the release zone. The satellite data presented here cannot measure or classify dump concentrations except by broad categories such as fresh, moderately dispersed and dispersed. However, with further ground truth it may be possible to monitor concentrations. One thing is certain, if enough of a difference in reflectance exists between the dump and surrounding water to appear on an image at satellite altitudes, there may be concentrations of material above the legal level.

1.0 INTRODUCTION

1.1 Purpose and Objectives

The coastal zone has been one of the most difficult areas for the New Jersey Department of Environmental Protection (NJDEP) to manage because of the complex variety of data required for decision making. For NJDEP, effective coastal resources management is dependent upon many factors, but ultimately management decisions are based on limited data. Often, inadequate data must be used because better information is difficult or too costly to obtain. Because of the dynamic nature of the coastal environment, timely data in usable formats are needed in New Jersey and other coastal states for routine decision making and effective allocation of state financial resources.

The primary objective of this ERTS-1 investigation was to develop quasi-operational information products and techniques from analysis of ERTS-1 imagery and collateral aerial photography and to incorporate these products into the State's management structure.

A secondary but important objective was the development of a user capability for future remote sensing activities in the State. Operational use of remote sensing data within the NJDEP has been demonstrated in this investigation; the application areas in which ERTS data has a significant input will benefit all coastal states.

Some of the original technical objectives of this investigation were modified to ensure responsiveness to specific operational problems. However, the intent of the original objectives was met. For example, an original objective, "to locate and study the dynamic characteristics of coastal current systems", implied use of these current data in pollution dispersion, coastal engineering projects for the planning of ocean outfalls, etc. The specific objectives of this investigation as developed in close consultation with NJDEP were:

- To study the dynamic characteristics of coastal and estuarine current systems as applicable to practical coastal pollution and engineering problems.
- To locate shore protection structures and to understand areas of serious coastal erosion so as to better allocate State funds.
- To monitor developmental and ecological changes within the coastal zone.
- To delineate the coastal zone into unique, homogenous ecological units.
- To monitor the environmental impact of dredging, filling and dumping of waste materials in the nearshore waters along the coastal zone.
- To locate ocean outfalls in relation to the total marine environment especially coastal current systems.

The results derived from these study objectives will be reported upon in the following sections.

This ERTS experiment has demonstrated to New Jersey that an integrated ERTS and aircraft remote sensing operational program can provide useful information for effective decision making on coastal resource problems within the Department of Enviromental Protection.

1.2 SUMMARY

This ERTS-1 investigation focused on development of quasi-operational practical information products using ERTS-1 imagery and collateral aerial photography. These products were applied to the regulation, protection and management of New Jersey's coastal environment by the New Jersey Department of Environmental Protection (NJDEP). Procedures for the operational use of ERTS-1 data products within various operating agencies within NJDEP were formulated.

Analysis and product preparation for meeting operational needs centered on four major coastal resource problem areas: detection of coastal zone changes; siting of ocean outfalls; monitoring of offshore waste disposal; and calculation of beach recession rates along the Atlantic Shore. Benefits derived from products developed from ERTS and aircraft imagery for each problem area were determined. A capability to use and understand remote sensor-derived information was developed within the State, and the application of this information to meet the requirements of current and anticipated coastal zone legislation was demonstrated.

ERTS data has increased the efficiency of coastal zone management in several areas. Many ERTS-derived products have been evaluated. Some have been found to be of annual or one-time-only value, while other ERTS products have provided necessary repetitive information. For operational needs, ERTS data alone has proven or appears to have value in (1) developmental and ecological change detection, (2) waterfowl game management (3) offshore waste disposal, and (4) floodplains mapping. Greatest overall benefit to the State has

accrued from analysis of ERTS-1 data coupled with a well coordinated aircraft and ground data collection system. Problems of shore erosion and siting of ocean outfalls were investigated most efficiently through this approach.

For the resolution of specific coastal resource problems, this investigation indicates that ERTS overpasses coupled with repetitive aircraft coverage can be productive and cost effective.

The investigators note a need for shorter time intervals between repetitive ERTS coverage, at somewhat higher spatial resolutions, and greater speed in delivery of ERTS data from NASA to make the system of delivery of ERTS analytical products operationally efficient within NJDEP.

The success of this ERTS investigation in addressing these coastal resource problems and the cost effectiveness of ERTS data have convinced the State of New Jersey to include monies in its FY 75 budget to participate in the general coastal zone management activities addressed within this investigation.

2.0 BACKGROUND

2.1 General

In January of 1970, when advised by NASA of the anticipated launch of the Earth Resources Technology Satellite, the NJDEP had already begun to investigate the potential benefits which might accrue from the application of repetitive synoptic imaging systems and was anxious to participate in the ERTS program. The Commissioner of Environmental Protection, Mr. Richard Sullivan, and members of his staff, Mr. Roland Yunghans and Dr. Edward Feinberg, recognized the need to protect rapidly diminishing state coastal resources which included the wetlands and adjacent coastal waters. Particular concern was directed to the impact of development on coastal areas and the development of appropriate coastal regulations in cooperation with various agencies. They recognized that the cost of using ground methods to measure a large number of coastal phenomena would be prohibitive and were beginning to develop an operational remote sensing capability to monitor coastal environments. NJDEP hypothesized that synoptic ERTS-1 imagery might provide an easily retrievable, timely and cost effective information base (in conjunction with high and low altitude aircraft photography) for routine decision making.

Dr. Feinberg and Dr. Frank J. Wobber of Earth Satellite Corporation (EarthSat) discussed the applications of small scale imagery with potential users within NJDEP. Simulated ERTS imagery was used to assess ERTS type imagery for operational problem solving. Gemini and Apollo photography of various coastal areas covering a range of coastal phenomena were distributed to Department personnel. Technical publications by Dr. Wobber (1968_a, 1968_b, 1969_a, 1969_b) and Mairs (1970) were also reviewed by members of the Department. While there was concern by both NJDEP and EarthSat that the spatial resolution and frequency of coverage of ERTS might be suboptimal for addressing the operational problems, it was agreed that the synoptic view of coastal areas provided by ERTS could benefit the State's coastal zone management program.

In this manner, a preliminary program plan to operationally apply ERTS imagery was developed. Essential to the program plan was the integration and use of other data collected from aircraft and ground teams. Recent color and color IR (Figure 1) imagery at 1:12,000 scale was available for the entire test area. In addition, a ground truth support plan was prepared by Dr. Feinberg for selected satellite overpass dates to include personnel, surface craft, and marine sampling equipment. State support available to this investigation was evaluated and a judgement was made that if NASA funding could be acquired, State financial and personnel resources would be committed.

As Co-Principal Investigators, Mr. Yunghans, Dr. Wobber, and Dr. Feinberg placed primary emphasis on problems of New Jersey shore protection, and the environmental monitoring of coastal areas. With the 18-day repetitive ERTS coverage, it was anticipated that environmental targets of opportunity such as offshore oil spills, clandestine ocean dumping, or the effects of severe storms

FIGURE 1. A 1:12,000 COLOR INFRARED PHOTOGRAPH OF A COASTAL INLET IN NEW JERSEY TAKEN AS PART OF THE "WETLANDS ACT" DATA ACQUISITION. DETAIL ON NAVIGATION CHANNELS, NATURAL STREAMFLOW, TIDAL HYDRAULICS, AND SEDIMENTATION PROCESSES CAN BE READILY OBSERVED FROM THIS PHOTOGRAPHY AND WAS USED AS GROUND TRUTH DURING THIS INVESTIGATION.

on coastal barrier islands (if they occurred) could be observed in a time frame that would allow some remedial actions. Essential to the quasi-operational nature of the investigation was flexibility, an anticipated need to modify the focus of the experiment, when necessary, to obtain practical results. The benefits to be derived from ERTS image applications would be described, and dollar benefits defined. The focus of the experiment on practical ERTS applications anticipated NASA guidelines for ERTS-B experiments.

The ERTS proposal was reviewed to better define the requirements of various State agencies, and to expand the quasi-operational program plan. Governor Cahill's support of the investigation was obtained and is gratefully acknowledged.

2.2 Previous Remote Sensing Investigations

Much previous work on various aspects of coastal zone management reaches the general conclusion that analysis of the nearshore marine environment and nearshore processes is among the most promising applications of orbital satellite systems.

A review of the literature reveals that the Coast and Geodetic Survey began using early color photography to determine various coastal parameters such as under-water detail in clear coastal waters. The technique of water current measurements from aerial photography had been successfully applied by Cameron in 1960 and applied his results to coastal engineering problems in Nova Scotia. Surface tidal currents have also been successfully measured from photography by the Coast and Geodetic Survey (Keller, 1963).

In Lake Erie, color photographs have been used to identify flow patterns, especially as related to the discharge of polluted wastes into the lake (Schneider, 1968). Lepley (1968) demonstrated the feasibility of mapping ocean water clarity from spacecraft photography. Scherz (1967) conducted work on the detection of pollution sources with the use of various film and filter combinations. Silvestro (1969, 1970) had obtained and analyzed narrow band spectral reflectances of various environmental features pertinent to water quality. The use of aerial photography for the investigation of coastal erosion which is caused by the changing conditions of tides, waves, and currents has been well documented by Stafford (1968), and his work was used as a basis for the erosional work conducted as part of this investigation. The use of both black and white and color infrared photography to delineate shorelines has become a well established procedure. Conrod et.al. (1968) used aerial photography to record features that are visible on the ocean bottom and have attempted to classify the bottom and catalogue plant species in relation to their spectral signatures recorded on the film. Anderson (1969), Wobber and Anderson (1972), and Pestrong (1969), have all shown the possibilities of using remote sensing techniques for the discrimination of marshland areas.

The principals of multispectral aerial photography have been presented by Yost and Wenderoth (1967, 1968), Ross (1968), and Ross and Jensen (1969). Previous to ERTS, multispectral photography was the main optical tool for gathering information in the visible and near infrared region. Both systems are based upon electromagnetic energy being recorded in several discrete spectral regions, followed by various processes for comparing or combining them, to discriminate or enhance a particular subject, or its main features, by the differences between its spectral reflectances and those of the background. A desirable spectral band is one in which the reflected energy from the object of interest is different from that of the background material. The spectral bands as found on the ERTS-MSS are such that discriminations between coastal resource features are readily discernible.

These early remote sensing investigations and previous work done by the investigators (Mairs, [1970, 1971_a, 1971_b, 1972]; Wobber [1967, 1968, 1969, 1970, 1971]) demonstrated the possible techniques that could be used for increasing the reliability of decision making processes within State governments. This previous work further encouraged NJDEP to undertake a joint relationship with EarthSat to determine the effectiveness of ERTS data inputs to coastal resource management within the State.

3.0 METHODS AND APPROACH

3.1 State Interviews

In order to establish the utility of ERTS data for addressing operational problems in coastal New Jersey, the investigators first needed to determine those legislative, regulatory, and administrative responsibilities of the State which might benefit from ERTS data. The investigators developed an understanding of State programs and procedures while communicating the potentials of repetitive satellite data to likely State users. Informal dialogue with State officials initiated at the time the ERTS-A proposal was written, continued throughout the investigation. Formal meetings and interviews with NJDEP personnel began shortly after the start of the investigation and continued throughout.

Interviews were conducted in those agencies blocked out on the NJDEP Organization Chart (Figure 2). The interviewers developed a preliminary questionnaire (Figure 3) to aid in their discussions with state personnel. Findings for each agency were summarized on Interview Record Forms (Figure 4). The interviews followed a general format in which the interviewers briefly described the investigation, the agency personnel described their legislative and administrative responsibilities and their data needs, and finally all parties discussed possible operational application of ERTS data. While a principal objective of the interviews was to identify repetitive data needs which might be supplemented or surplanted by ERTS data, many one-time needs were also identified.

Rather than recount each of the interviews the principal potential applications which were identified will be discussed, and the data users identified.

STATE OF NEW JERSEY
DEPARTMENT OF ENVIRONMENTAL PROTECTION

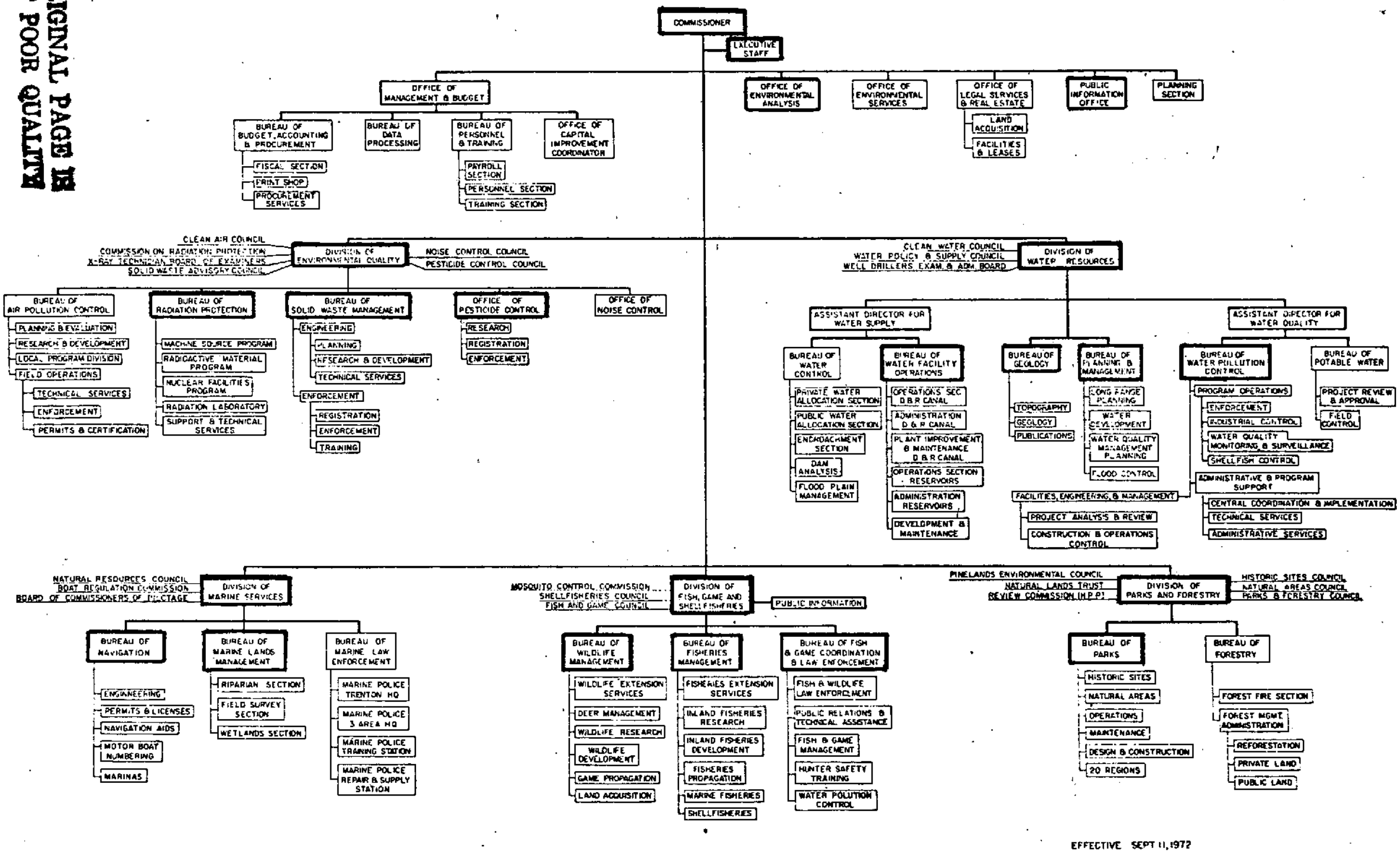


FIGURE 2

FIGURE 3

ENVIRONMENTAL DATA REQUIREMENTS QUESTIONNAIRE

DESCRIPTION OF ADMINISTRATIVE OF OPERATIONAL FUNCTION	INDIVIDUAL	
	BUREAU	
DATA NEEDS	WHAT DATA DO YOU USE?	
	WHAT ADDITIONAL DATA COULD YOU USE?	
PRODUCT FORMAT	YOUR CURRENT PRODUCT	
	WOULD OUR SAMPLE PRODUCTS BE USEFUL?	
	IS THERE SOME OTHER FORMAT?	
DELIVERY REQUIREMENTS	HOW OFTEN DO YOU DELIVER?	
	WHAT RESPONSE TIME DO YOU HAVE?	
	WHAT ACCURACY NEEDED?	

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 4

INTERVIEW RECORD FORM

PRELIMINARY INTERVIEW NOTES
(ERTS)

PUBLICATIONS REPORTS

VE	I
NE	

BRIEFING

- NAME: ROCCO GERERARI — ATLANTIC COASTAL BASIN — 10/4/72
- POSITION/OFFICE: WATER POLLUTION CONTROL BUREAU
- TELEPHONE:
- DESCRIPTION OF GENERAL RESPONSIBILITIES: Bob Vincent, Chief Engineer, Paul Schorr, Wednesday degree of treatment, location of outfalls, thermal (Steve Neiswand) Statewide responsibilities

MANAGEMENT DECISIONS (confidence assessment)	DATA NEEDS	PRESENT APPROACH	FORMAT PRESENT AND DESIRED	RESPONSE (TIME) REQUIREMENT	ESTIMATED MAN MONTHS TO PREPARE	BUDGET (dollars)
1. Location & regional outfalls	dillution ratio ocean outfalls	local gov'ts consulting studies				
Proposal for discharge permits - primary responsibility	Discharge standard					
Wastewater discharges	Environmental impact reports	In process (Guidelines)				
2. Sludge disposal						
3. Thermal pollution		No sampling program				
Guidelines and data gathering	Response to public requests	Send field man out to respond personally.				
Environmental impact requires interdisciplinary inputs						

COMMENTS

3.1.1 Repetitive Data Needs

Coastal current data. From these initial interviews, the most common and important need was found to be accurate data on the location and effects of seasonal and persistent currents along the New Jersey coast. Subsequent examination of Federal and State data showed that very little information was available. The Bureau of Radiation Protection required data on coastal currents in order to select and evaluate sites for offshore and estuarine nuclear power plants, several of which are now being designed.

The Division of Water Resources undertook a major program in 1964 to consolidate New Jersey's ocean, estuarine, and coastal riverine waste water outfalls into 10 to 20 major regional outfalls with substantially increased discharge rates. Outfalls must be designed so that the State's 115 miles of coastline are not polluted.

The Division of Marine Services is responsible for approving shore protection projects and allocating state funds for the construction of groins, jetties, seawalls, and bulkheads. In the past, their decisions have been based substantially upon the personal knowledge of the shoreline by the senior staff of the Bureau of Navigation, complemented by rather limited ocean current data. The setting of priorities for shore protection requires a knowledge of where the monies spent will have the greatest impact. This requires knowledge of the dynamic forces which erode the beaches.

Monitoring and Change Detection. The Bureau of Air Pollution Control requires data for administrative (rather than enforcement) purposes on both the sources and fate of air pollutants. The Division of Water Resources requires data on the fate of discharges from ocean outfalls. The Bureau of Navigation has monitored coastal changes since 1950 through annual aerial photography; ERTS data was identified as a possible complement or substitute for these missions.

Both the Division of Marine Services and the Divison of Fish, Game, and Shellfisheries are concerned with monitoring wetlands. Under the State's Wetlands Act of 1970, the Division of Marine Services has the responsibility for conducting a permit program and monitoring all activites in the wetlands. The Division of Marine Services also must regulate the entire coastal zone under the Coastal Area Facility Review Act. With a small inspection force and some 1800 square miles of New Jersey under regulation, the Division requires some form of frequent serveillance which will enable them to identify and halt prohibited activities. The Division of Fish, Game, and Shellfisheries indicated that it must make a variety of fish and game management decisions which require data on wetlands including the amount of forage crop annually available for waterfowl.

3.1.2 Non-Repetitive Data Needs

Each of the agencies interviewed identified data needs which might be met by ERTS but which were non-repetitive or required infrequent coverage. These were generally in the areas of planning, site selection including decisions on the acquistion of park lands, and general resource inventories.

3.2 Priorities

Following the interviews with State officials a priority listing of these state needs and problem areas emerged. Information products were tailored to meet specific problems of immediate concern to NJDEP. These needs are categorized as follows:

- marine current circulation patterns
- shoreline erosion and accretion
- monitoring of ecological and developmental changes
- coastal zone delineation
- movement and dispersion of ocean dumped wastes
- ocean outfall placement and dispersion of effluents

These were the problem areas initially addressed in the ERTS analysis. In following sections the products and results of these efforts will be discussed.

3.3 Collateral Data Collection

In order to provide relevant collateral data which could be used as an auxiliary reference during the course of the investigation, a detailed search of various data banks was completed during the early phase of this study. Information on existing aircraft data, ground truth data, and technical literature related to coastal protection was collected and collated.

An information retrieval system was established through the development of a geographic cross-referenced card catalog[1/] which utilized 3" x 5" index cards. In addition to the card catalog, relevant geographic data was plotted on 1:250,000 scale topographic maps of New Jersey and this information was keyed to the card catalog. A sample card is shown in Figure 5.

3.4 Test Area and Ground Truth

The test area[2/] for this investigation was the New Jersey Atlantic shore extending from latitude 38° 47' N to 40° 33' N.

1/ Major subject headings listed in the card catalog included the following: aerial photography, beach erosion, bibliography, climatology, coastal structures, dump sites (offshore), estuarine circulation, geology (coastal), glossary (coastal terms), inlets, maps (nautical charts, geology topography, etc.), ocean dumping, offshore circulation, outfall sites, planning (coastal zone), sediment transport, tide data, tracers, and water resource data (surface waters/quality).

2/ The study area lies within the coastal plain province of Eastern North America, which extends seaward to the edge of the continental shelf. The land portion of this province is bounded on the northeast by Raritan Bay and on the west by the Delaware River and the Delaware Bay. The land rises gradually from the sea as a moderately dissected plain to elevations of about 300 feet, sloping off toward both the Raritan River and the Delaware River drainage systems. The submerged portion of the plain has a gentle southeastward slope of 5 or 6 feet per mile for nearly 100 miles to the edge of the continental shelf.

The New Jersey shoreline at the land-water interface can be divided into several distinct physiographic sections. At the northern end, the 19 miles of shoreline from Monmouth Beach to Bay Head, called the Headland Section, eroded back several miles during recent geologic time. Some material eroded by the sea from this headland was transported by currents southward, and some was transported northward to form the spit called Sandy Hook. A barrier beach broken by 10 tidal inlets comprises the central portion, which extends about 90 miles down the coast from Bay Head. Historic and geologic evidence shows that the general locations of many inlets has been constant for a long period of time, although the exact location of inlets has been succeptible to change. At the southern end, the barrier beach rejoins the mainland which extends for about 3 miles at Cape May.

Inland from the barrier beaches can be found a series of estuaries, tidal marshes, creeks, thoroughfares, and lagoons which range from 2 to 5 miles wide. The upland immediately adjacent to the shore areas can be classed as lands that influence the remaining coastal resources and are environmentally important for the survival of the whole system.

Atlantic City,
New Jersey

Beach Erosion

Atlantic City, New Jersey, Beach Erosion Control Study;

House Document No. 325, 88th. Congress, 2nd. Session;

1964; pp ______.

- Littoral Materials - Waves, Currents, Winds
- Littoral Forces - Storms, Tides, Shore History
- Shoreline and offshore changes - Profiles
- Volumetric accretion and erosion

FIGURE 5

Over 300 index cards were prepared. They are on file at EarthSat's Washington, D. C. facility.

During the investigation legislation was passed which legally defined the coastal zone and subsequently the legally defined limit of the coastal zone was used as the inland boundary of the test area.

Following interviews with a variety of NJDEP personnel and an assessment of the NJDEP data acquisition network, the concept of fixed test sites within the test area was revised. The general approach to the selection of fixed test sites within the test area evolved into being responsive to the interdisciplinary needs and problems within NJDEP; sites were chosen so as to respond to the dynamic nature of the environmental and coastal management problems of NJDEP. In addition, attention was given to coordinating other Federal and University ground truth activities that were taking place along the New Jersey coast. These collaborative efforts conducted with the National Oceanic and Atmospheric Administration and, Naval Oceanographic Office, provided an expanded data base for ERTS analysis.

Coastal areas of immediate concern to the State were sampled as necessary to provide data such as water quality, physical characteristics, major tidal and wind-driven circulation, and other parameters needed to analyze any problem requiring prompt action, e.g., red tide, major nearshore pollution, severe storm erosion, etc. Every attempt was made to conduct field and light aircraft data collection surveys concurrent with ERTS-1 overpasses. These sampling surveys were a continuing effort focused on immediate response-reporting related to environmental problems as they occurred.

In addition to the routine sampling and field verification investigations discussed above, the investigators participated in a major ground truth study effort in the New York Bight area during March-April 1973. The test area included the northern portion of New Jersey and the New York Harbor - Raritan Bay area. This surface truth collection program involved thirteen separate governmental and private organizational components including three NASA aircraft which provided ERTS underflights on April 7, 1973. These aircraft provided complete sequential coverage throughout the day during a complete tidal cycle. Small boats (including those of NJDEP) operated along the coast and in Lower Sandy Hook; helicopters served as survey platforms and conducted measurements across regions of marked surface discontinuities.

This entire effort sponsored and coordinated by the National Environmental Satellite Service was conducted as a multi-altitude remote sensing operation (including ERTS-1) with concurrent collection of surface oceanographic and climatological data.

3.5 Analysis Procedures

3.5.1 General

All NASA ERTS-1 data products for the MSS sensor were used during this investigation. The uses and benefits of specific products for coastal resource problems are discussed in the RESULTS section. This section examines analysis techniques for each product type.

With one exception (ERTS CCT change detection) the 70mm positive transparancies were analyzed initially for all problem areas. As image sets were received, a "quick look" evaluation was conducted with emphasis on:

- Cloud cover and haze level
- Discolored (sediment-laden) current plumes
- Changing morphology of sub-aerial and submergent coastal landforms
- Nearshore waste disposal
- Shoreline construction projects
- Dredging and filling
- Wetland delineations
- Nearshore current indicators
- Coastal development
- Anomalous features

All obvious features impacting on the coastal environment were annotated during this initial analysis. This reconnaissance analysis procedure provided a means of referencing, by environmental phenomena, data that was useful for further analysis of successive image sets.

Each type of ERTS image product was made available to the investigators. The 70mm transparencies provided the most detail and the most information of all of the NASA hard copy type products; however, computer generated Litton prints were found to provide more detail and the best spatial resolution of all ERTS products. These Litton prints although providing superior information would ordinarily be costly to produce for most state offices. Color composites proved useful in conjunction with individual 70mm transparencies of each MSS band for vegetative and ecological changes but their low spatial resolution negated their use as individual analysis products. It was anticipated that the 9.5" x 9.5" precision processed transparencies would provide more information than the bulk process imagery, but this was not found to be the case. Precision processed images proved of poor quality and were of limited value.

The relative interpretability of the four MSS bands for various coastal phenomena was assessed (Table 1). These conclusions were reached after comparative study of the same features on each image. The number scale represents (1) as being the best and (4) providing the least information. Where the same rating was given to 2 bands, it was judged that there was no consistent difference in interpretability.

TABLE 1

ASSESSMENT OF ERTS MSS FOR VARIOUS
RESOURCE FEATURES

	4(.5-.8 m.)	5(.6-.7 m.)	6(.7-.9 m.)	7(.8-1.1 m.)
land-water interface	4	3	2	1
wetland-upland interface	3	1	3	2
land patterns	2	1	4	3
coastal current patterns	2	1	3	4
forest types	2	1	2	2
road network	2	1	4	3
urban core detail	4	1	3	2
offshore wast disposal	2	1	3	4
estuarine flushing	2	1	3	4
development change detection	2	1	4	4

3.5.2 Enhancement Techniques

Several enhancement techniques were applied to the ERTS frames in an attempt to bring out subtle contrast differences between the resource problem of interest and the background. Density slicing procedures (Digicol) were tested for discriminating dispersion characteristics of offshore waste materials. However, other than assigning false colors to the waste materials and the background waters, no additional information could be gained from the density slicing operations.

Additive color viewing was successfully used for extracting dispersion information on the offshore waste materials. Accurate discrimination of a well dispersed dump (September 22, 1972) was facilitated on a color additive viewer by increasing the gamma of the ERTS 70mm negatives to a value of between 3 and 4.

Computerized analysis techniques proved highly beneficial for enhancing and discriminating resource features. Computer generated Litton prints were used for circulation analysis in which dye streamers 20 meters wide were imaged and further in a change detection system of development/ecological alterations. These analysis techniques as they refer to the specific problems are discussed in the RESULTS section under each problem area discussion. Computer processing of the September 22, 1972 and April 7, 1973 ERTS overpasses has yielded information that was not discernible in any of the film products sent out from NASA or in subsequent enlargements of these frames. Computer generated prints and shade prints were very useful in offshore waste disposal analysis, developmental/ecological detection and in circulation analysis. A computer classification of water types based on intensity levels offshore New Jersey was possible using the intensity level histogram of the shade prints.

4.0 RESULTS

4.1 Baseline Information

As discussed in the INTRODUCTION, the investigation centered on two separate and distinct groups of objectives: (1) The development of a capability within NJDEP to use remote sensor derived information products and (2) applications of ERTS imagery to help solve practical coastal management problems. As a result, two categories of information products emerged.

Figure 6 lists individual products developed during the experiment, their relationship to experimental objectives, and their contribution(s) to the various operating Divisions within the NJDEP. Many of the products contribute to routine decision making activities within NJDEP while others address only one-time or yearly needs. Other products were used to develop the capability within NJDEP to utilize ERTS and aircraft remote sensor data:

- Aircraft Coverage Catalogue (existing NASA aircraft coverage was catalogued for reference during the investigation)
- ERTS-1 Reference Manual (a handbook was prepared and circulated throughout NJDEP detailing the objectives of the investigation, the ERTS satellite system and remote sensing technology in general)
- New Jersey Basemap 1:500,000 Black/White (Figure 7)
- Northern New Jersey Basemap 1:250,000 Black/White (Figure 8)
- Southern New Jersey Basemap 1:250,000 Black/White (Figure 9)
- State of New Jersey, 1:500,000 color
- Coastal Zone Remote Sensing Brochure for County/Municipal Groups (a brochure was prepared for distribution by NJDEP to local authorities interested in remote sensing capabilities).

FIGURE 6

PRODUCT UTILIZATION BY NJDEP OPERATING DIVISIONS

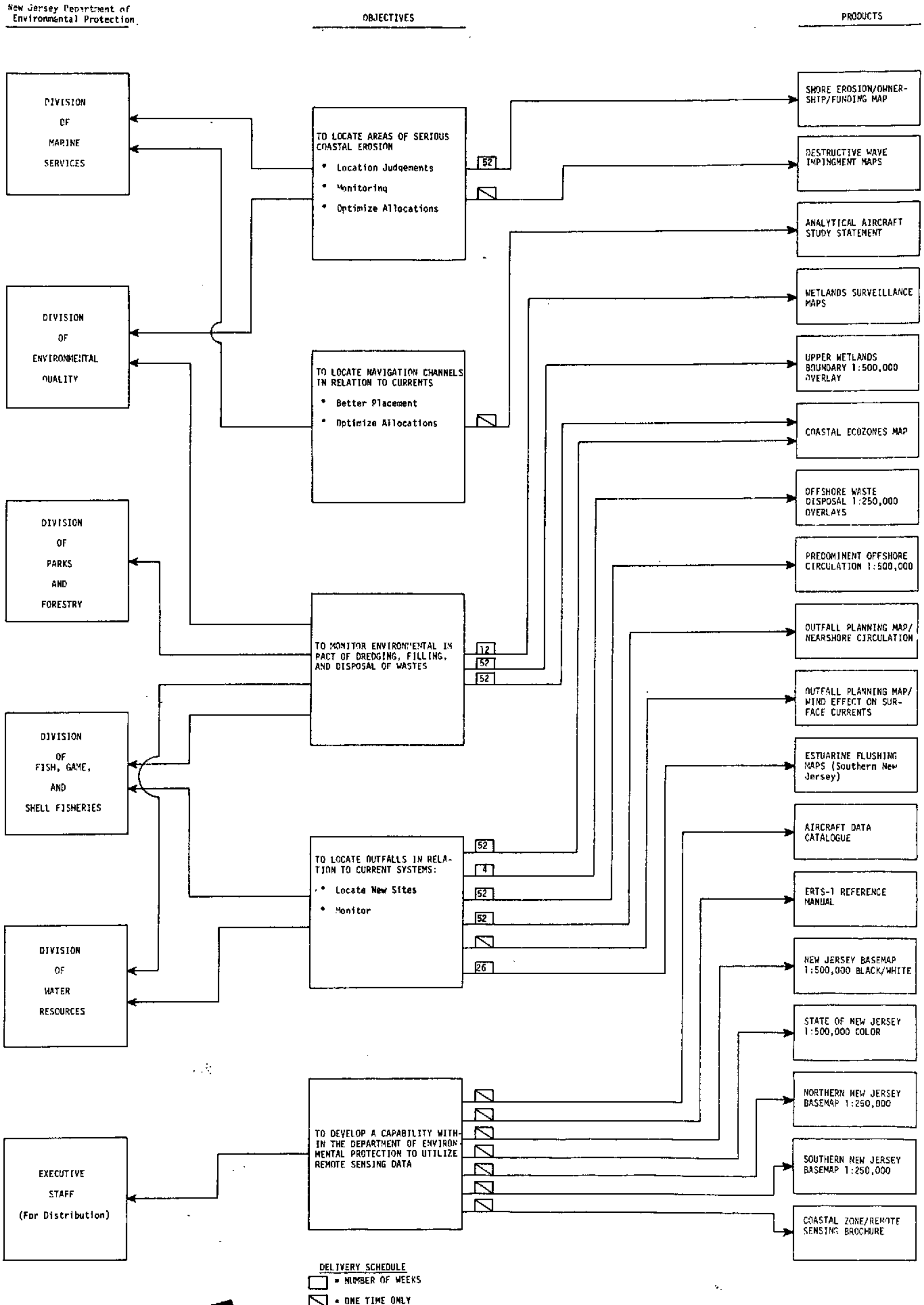

New Jersey Department of Environmental Protection
OBJECTIVES
PRODUCTS
DIVISION OF MARINE SERVICES
DIVISION OF ENVIRONMENTAL QUALITY
DIVISION OF PARKS AND FORESTRY
DIVISION OF FISH, GAME, AND SHELL FISHERIES
DIVISION OF WATER RESOURCES
EXECUTIVE STAFF (For Distribution)
TO LOCATE AREAS OF SERIOUS COASTAL EROSION
• Location Judgements
• Monitoring
• Optimize Allocations
TO LOCATE NAVIGATION CHANNELS IN RELATION TO CURRENTS
• Better Placement
• Optimize Allocations
TO MONITOR ENVIRONMENTAL IMPACT OF DREDGING, FILLING, AND DISPOSAL OF WASTES
TO LOCATE OUTFALLS IN RELATION TO CURRENT SYSTEMS:
• Locate New Sites
• Monitor
TO DEVELOP A CAPABILITY WITHIN THE DEPARTMENT OF ENVIRONMENTAL PROTECTION TO UTILIZE REMOTE SENSING DATA
52
12
52
52
52
4
52
52
26
SHORE EROSION/OWNERSHIP/FUNDING MAP
DESTRUCTIVE WAVE IMPINGMENT MAPS
ANALYTICAL AIRCRAFT STUDY STATEMENT
WETLANDS SURVEILLANCE MAPS
UPPER WETLANDS BOUNDARY 1:500,000 OVERLAY
COASTAL ECOZONES MAP
OFFSHORE WASTE DISPOSAL 1:250,000 OVERLAYS
PREDOMINENT OFFSHORE CIRCULATION 1:500,000
OUTFALL PLANNING MAP/ NEARSHORE CIRCULATION
OUTFALL PLANNING MAP/ WIND EFFECT ON SURFACE CURRENTS
ESTUARINE FLUSHING MAPS (Southern New Jersey)
AIRCRAFT DATA CATALOGUE
ERTS-1 REFERENCE MANUAL
NEW JERSEY BASEMAP 1:500,000 BLACK/WHITE
STATE OF NEW JERSEY 1:500,000 COLOR
NORTHERN NEW JERSEY BASEMAP 1:250,000
SOUTHERN NEW JERSEY BASEMAP 1:250,000
COASTAL ZONE/REMOTE SENSING BROCHURE
DELIVERY SCHEDULE
= NUMBER OF WEEKS
= ONE TIME ONLY

FIGURE 7

NEW JERSEY BASE MAP

NEW JERSEY ERTS-1 INVESTIGATORS BASEMAP

Let's protect our earth

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

THIS PHOTOMAP PRODUCED FROM A NASA ERTS-1 MOSAIC OF MSS BAND 5 TAKEN ON OCTOBER 9, 1972 HAS BEEN PREPARED FOR DISTRIBUTION WITHIN THE STATE OF NEW JERSEY'S DEPARTMENT OF ENVIRONMENTAL PROTECTION. CLEAR ACETATE OVERLAYS WILL BE PREPARED OF VARIOUS ENVIRONMENTAL PHENOMENA AS ANALYZED AND OBSERVED FROM ERTS-1 IMAGERY AND WILL SUBSEQUENTLY BE DELIVERED TO DEPARTMENT INVESTIGATORS.

N

SCALE 1:500,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 Nautical Miles

EARTH SATELLITE CORPORATION

1747 Pennsylvania Ave.
Washington, D.C. 20006

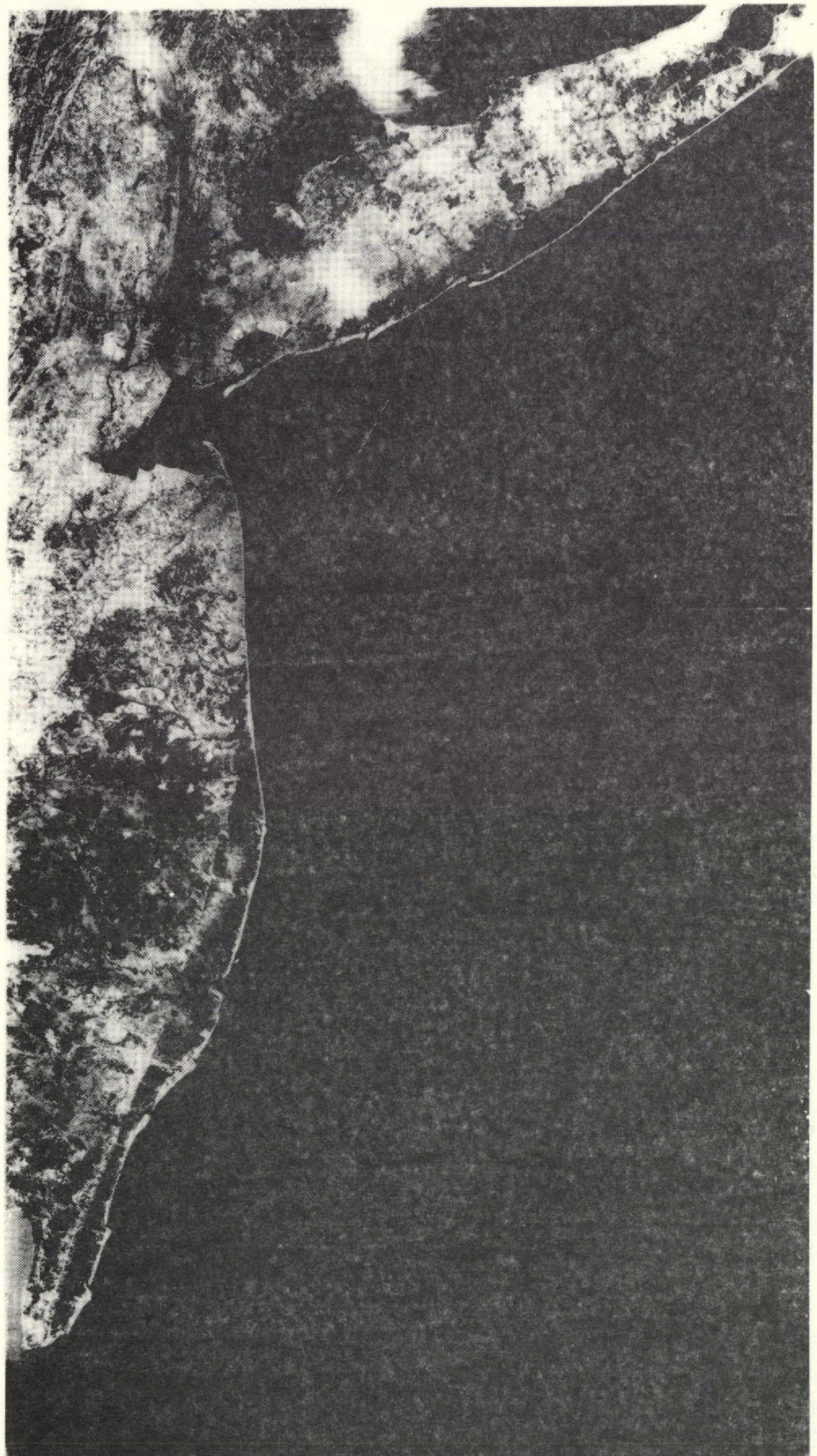
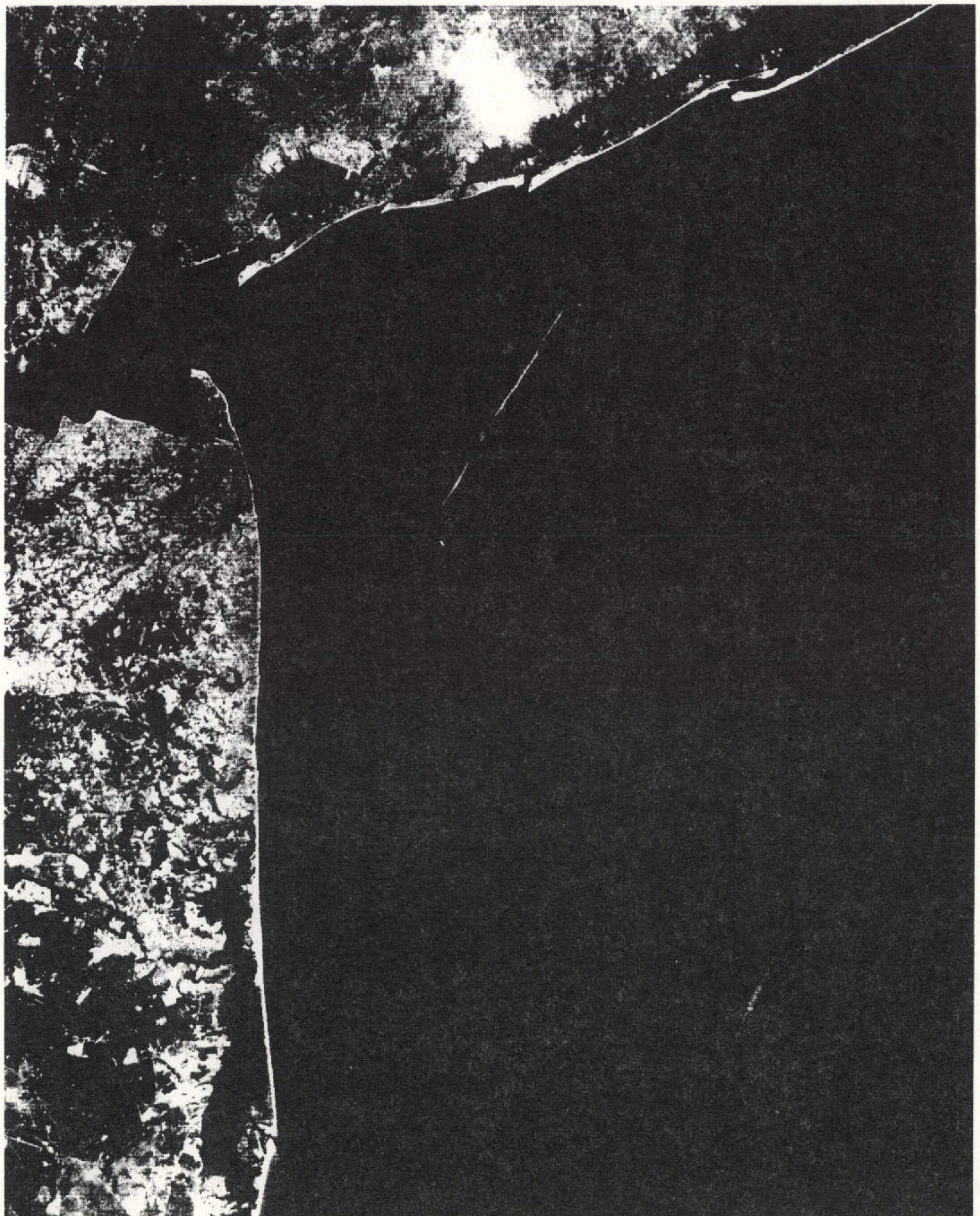


FIGURE 8

INVESTIGATORS' NEW JERSEY BASE MAP - NORTHERN SECTION

NEW JERSEY ERTS-1 INVESTIGATORS BASEMAP

NORTHERN SECTION



Let's protect our earth

**NEW JERSEY
DEPARTMENT
OF ENVIRONMENTAL
PROTECTION**

PHOTOMAP PREPARED FROM BULK PROCESSED MULTI-SPECTRAL SCANNER (MSS) IMAGERY ACQUIRED BY THE NASA EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS-1). THE IMAGE, BAND 5, WAS ACQUIRED IN THE RED (600-700 NM) PORTION OF THE SPECTRUM ON JANUARY 25, 1973. SUBSEQUENT OVERLAYS OF VARIOUS ENVIRONMENTAL PHENOMENA WILL BE DELIVERED TO NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION INVESTIGATORS FOR USE WITH THIS BASEMAP.

EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 Nautical Miles

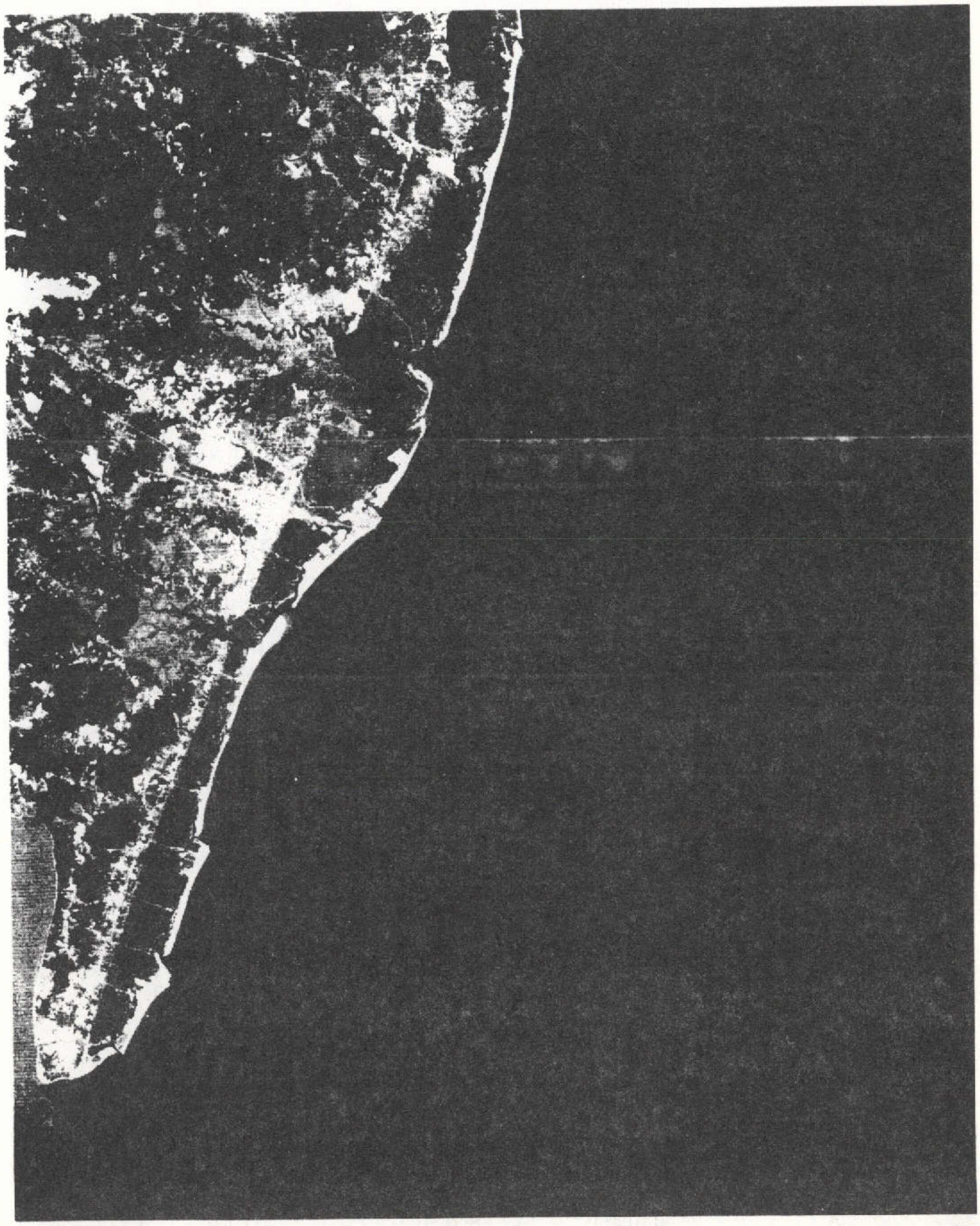
N

FIGURE 9

INVESTIGATORS' NEW JERSEY BASE MAP - SOUTHERN SECTION

NEW JERSEY ERTS-1 INVESTIGATORS BASEMAP

SOUTHERN SECTION



ORIGINAL PAGE IS OF POOR QUALITY

Let's protect our earth

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

PHOTOMAP PREPARED FROM BULK PROCESSED MULTI-SPECTRAL SCANNER (MSS) IMAGERY ACQUIRED BY THE NASA EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS-1). THE IMAGE, BAND 5, WAS ACQUIRED IN THE RED (600-700 NM) PORTION OF THE SPECTRUM ON JANUARY 25, 1973. SUBSEQUENT OVERLAYS OF VARIOUS ENVIRONMENTAL PHENOMENA WILL BE DELIVERED TO NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION INVESTIGATORS FOR USE WITH THIS BASEMAP.

EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 Nautical Miles

N

4.1.1 Nearshore Circulation Maps

Historical data on nearshore circulation dynamics were used to prepare clear acetate basemap overlays of tidal (Figure 10), wind-driven (Figure 11) and residual bottom current (Figure 12) conditions along the coast of New Jersey. These products provide base data on nearshore marine conditions. Each product illustrates probable current speeds and directions for various times within the tidal cycle and under various climatological conditions.

4.1.2 New Jersey Ecological Map

The synoptic view provided by ERTS was used to delineate regionally similar land areas; these were designated as "ecozones". Ecozones are defined as regional areas of at least 200 square miles characterized by homogenous inter-relationships of soils, landforms, vegetation, geology, and land use. The Ecozone Map and a descriptive brochure prepared from ERTS analysis[3/] were distributed throughout NJDEP (FIGURE 13).

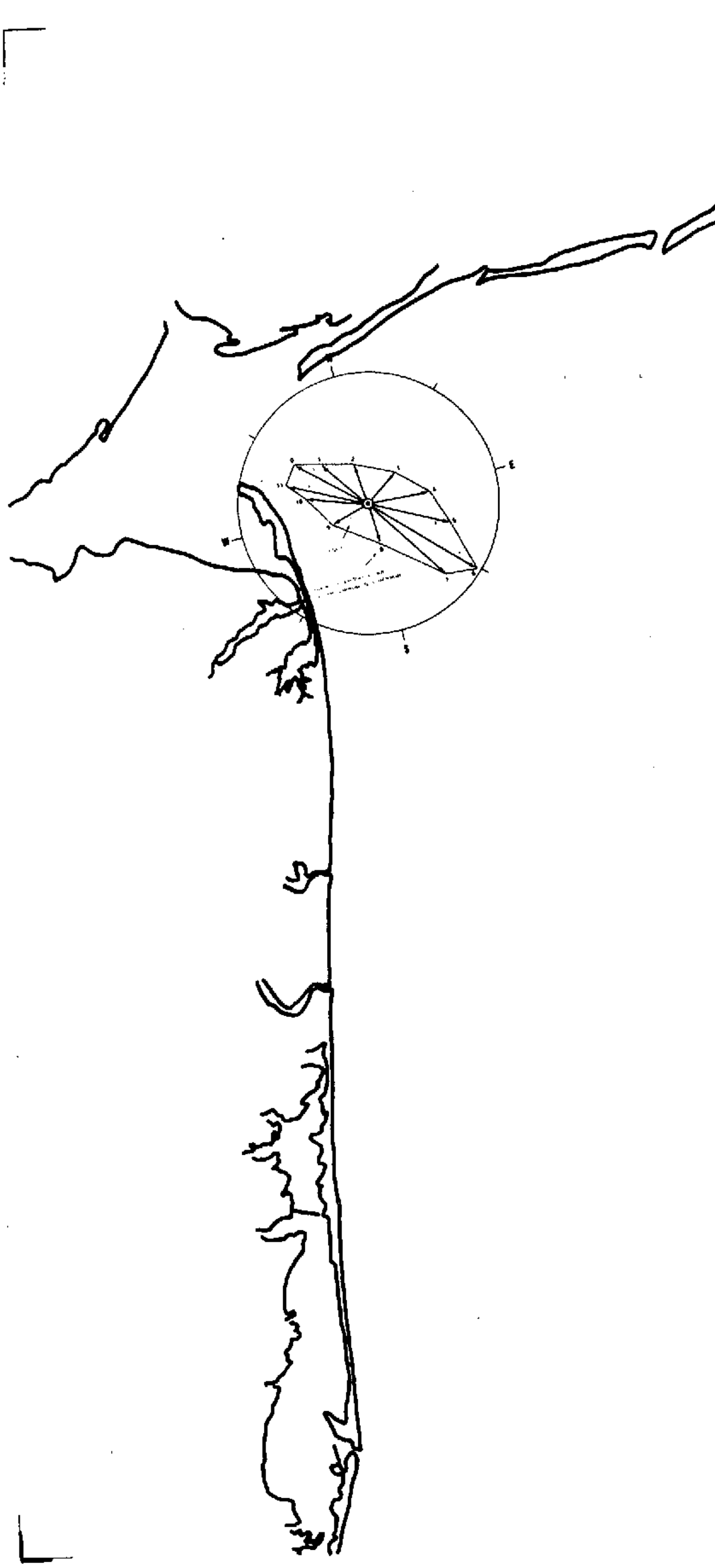
4.1.3 Coastal Area Map

An ERTS photomap of New Jersey's Coastal Area (Figure 14) was prepared for the Office of Environmental Analysis by combining MSS bands 5 and 7 for the October 10, 1972 orbit.

3/ Analysis of MSS Band 5 led to the delineation of fifteen ecozones. A line was drawn around each area which, according to its tone, texture, pattern and extent, appeared as a distinct land resource unit. For example, the Coastal Zone was delineated by the dark tones of the back-bay areas, the somewhat lighter tones of the wetlands, and the bright tones of the barrier beaches. The Pine barrens imaged as a dark toned, velvety, textured, extensive land area broken only by a few light toned roads and dark toned dendritic patterns of river drainage networks. The Agricultural Belt imaged a very light mottled tone of highly reflective vegetative areas. Urban and industrial areas around Trenton, Camden, and Newark, were distinguished by their subtly mottled, light grey tones.

FIGURE 10

ROTARY TIDAL CURRENTS



OVERLAY FOR NEW JERSEY ERTS-1
INVESTIGATORS BASE MAP
NORTHERN SECTION

ROTARY TIDAL CURRENTS

ROTARY TIDAL CURRENTS

OFFSHORE THE TIDAL CURRENTS ARE NOT CONFINED TO A DEFINITE CHANNEL. THEREFORE, THERE IS NO SLACK PERIOD BETWEEN EBB AND FLOW OF THE TIDE. IN A TIDAL CYCLE OF 12½ HOURS THE CURRENT WILL HAVE MOVED IN ALL DIRECTIONS OF THE COMPASS.

THE VECTORS IN THE DIAGRAM REPRESENT THE DIRECTION OF THE CURRENT AND THE VELOCITY OF THE TIDAL CURRENT IN KNOTS. THE HOUR ASSOCIATED WITH EACH VECTOR IS THE NUMBER OF HOURS AFTER MAXIMUM FLOOD AT THE NARROWS, NEW YORK HARBOR.

THE VELOCITIES GIVEN IN THE DIAGRAM ARE AVERAGE. THE MOON AT NEW, FULL, OR PERIGEE TENDS TO INCREASE THE VELOCITIES 15 TO 20 PERCENT ABOVE AVERAGE. WHEN PERIGEE OCCURS AT OR NEAR THE TIME OF NEW OR FULL MOON THE VELOCITIES WILL BE 30 TO 40 PERCENT ABOVE AVERAGE. QUADRATURE AND APOGEE TEND TO DECREASE THE VELOCITIES BELOW AVERAGE BY 15 TO 20 PERCENT. WHEN APOGEE OCCURS AT OR NEAR QUADRATURE THEY WILL BE 30 TO 40 PERCENT BELOW AVERAGE. THE VELOCITIES WILL BE ABOUT AVERAGE WHEN APOGEE OCCURS AT OR NEAR THE TIME OF NEW OR FULL MOON AND ALSO WHEN PERIGEE OCCURS AT OR NEAR QUADRATURE. THE VELOCITIES AND DIRECTIONS ARE FOR THE TIDAL CURRENT ONLY AND DO NOT INCLUDE THE EFFECT OF WINDS.

HORN BOUY ROTARY TIDAL CURRENTS	40°27', 73°55'

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Washington, D.C. 20006

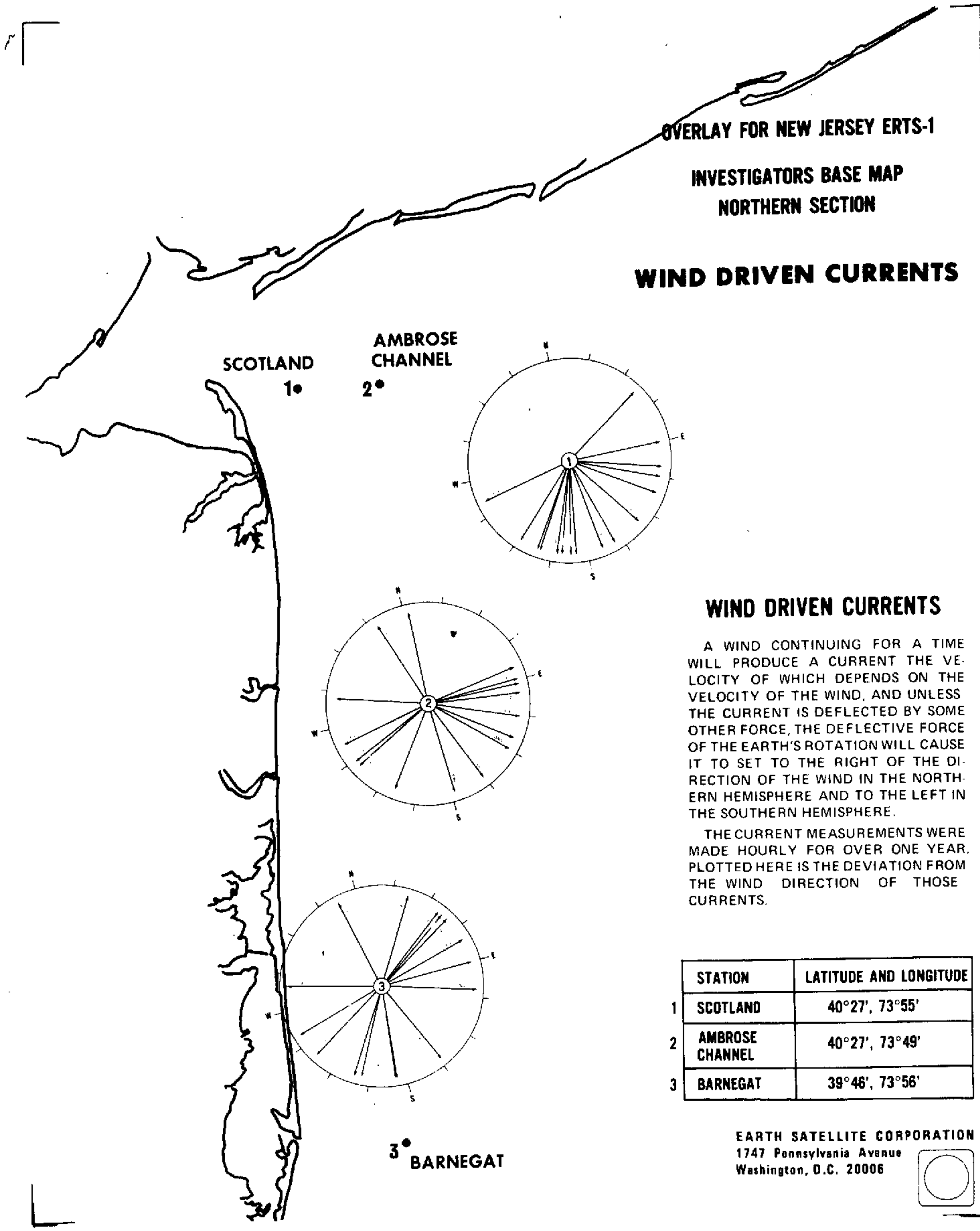
FIGURE 11

WIND DRIVEN CURRENTS

OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

WIND DRIVEN CURRENTS



WIND DRIVEN CURRENTS

A WIND CONTINUING FOR A TIME WILL PRODUCE A CURRENT THE VELOCITY OF WHICH DEPENDS ON THE VELOCITY OF THE WIND, AND UNLESS THE CURRENT IS DEFLECTED BY SOME OTHER FORCE, THE DEFLECTIVE FORCE OF THE EARTH'S ROTATION WILL CAUSE IT TO SET TO THE RIGHT OF THE DIRECTION OF THE WIND IN THE NORTHERN HEMISPHERE AND TO THE LEFT IN THE SOUTHERN HEMISPHERE.

THE CURRENT MEASUREMENTS WERE MADE HOURLY FOR OVER ONE YEAR. PLOTTED HERE IS THE DEVIATION FROM THE WIND DIRECTION OF THOSE CURRENTS.

	STATION	LATITUDE AND LONGITUDE
1	SCOTLAND	40°27', 73°55'
2	AMBROSE CHANNEL	40°27', 73°49'
3	BARNEGAT	39°46', 73°56'

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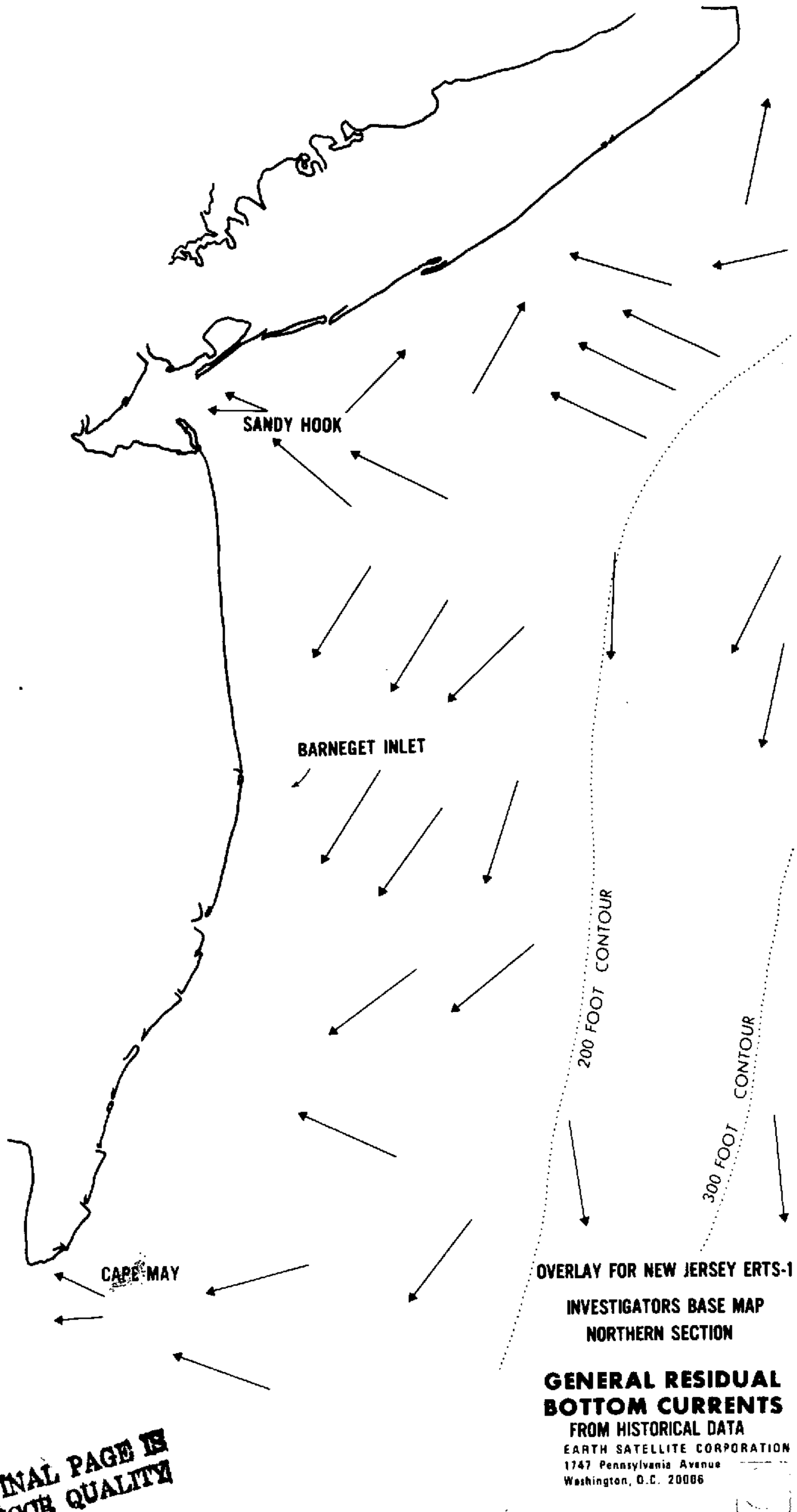

SANDY HOOK
BARNEGET INLET
CAPE MAY
200 FOOT CONTOUR
300 FOOT CONTOUR
OVERLAY FOR NEW JERSEY ERTS-1
INVESTIGATORS BASE MAP
NORTHERN SECTION
GENERAL RESIDUAL
BOTTOM CURRENTS
FROM HISTORICAL DATA
EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006

FIGURE 12

FIGURE 13

NEW JERSEY ECOLOGICAL MAP

REGIONAL ECOLOGICAL MAP
NEW JERSEY

Let's protect our earth

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

Ecozones are defined as regional areas characterized by homogenous interrelationships of soils, landforms, vegetation, geology, drainage, and land use. Because of their regional areal size (at least 200 square miles) and uniform characteristics, ecozones should logically be recognized as integral regional planning units. Within New Jersey, certain ecozones contain critical environmental resources worthy of special protection and regulation: Coastal Zone (coastal bays and wetlands); Pine Barrens (unique forest associations and extensive aquifer zone); Agricultural Belt (prime agricultural land); Highlands and Kittatinny Mountain (relatively undisturbed forest areas). A small scale, synoptic view is required for the recognition and delineation of regionally similar land areas. Earth Resources Technology Satellite (ERTS) imagery is ideally suited for this purpose because each image covers approximately 10,000 square miles. Portions of only three ERTS-1 images were required to prepare this mosaic base on which the ecozones of New Jersey have been mapped.

LEGEND

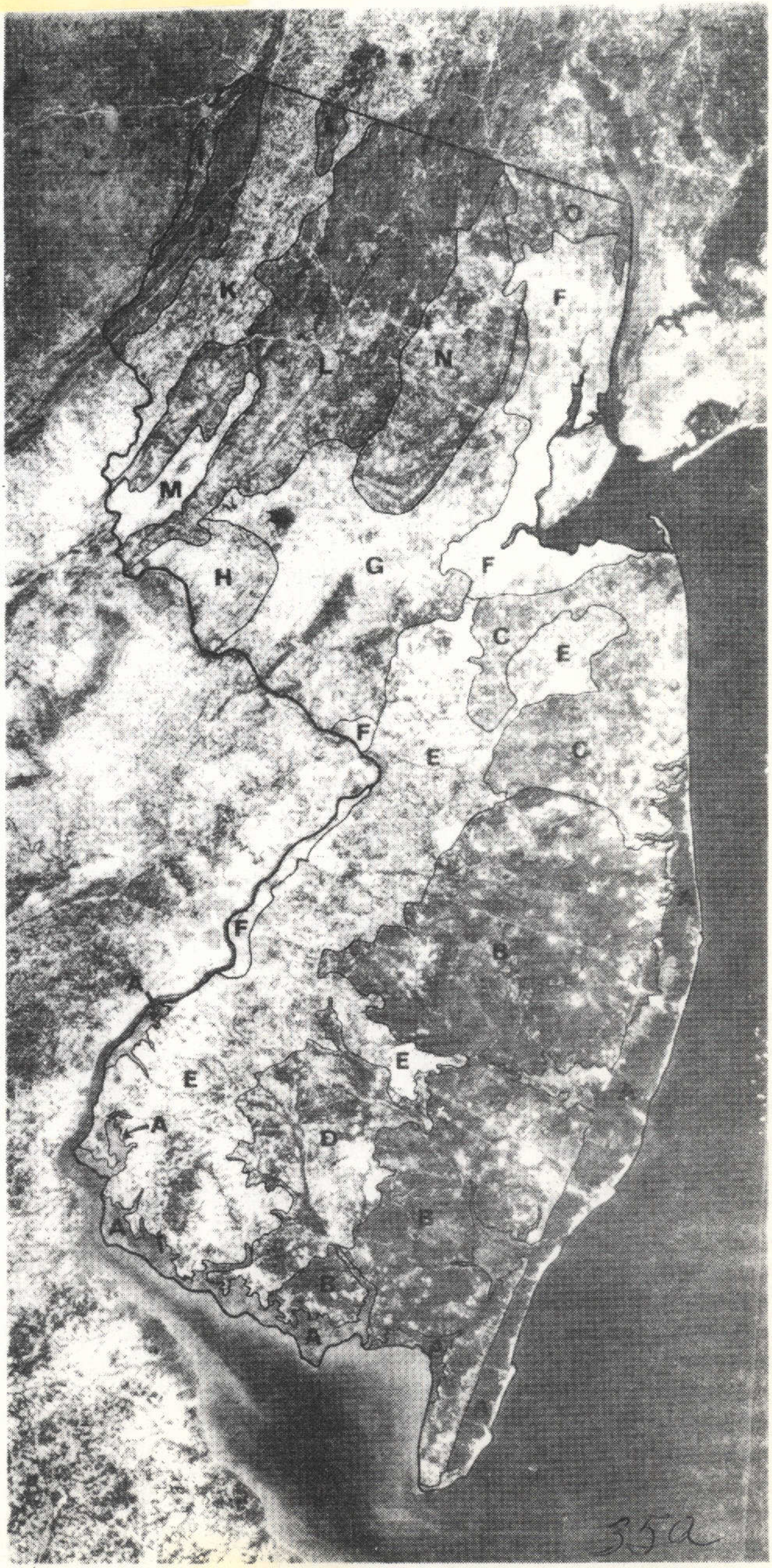
- **A COASTAL ZONE:** coastal lands, wetlands and water directly affected by coastal processes
- **B PINE BARRENS:** contiguous forest cover with low intensity land use
- **C LAKEWOOD:** forested area with mixed residential and commerical land use
- **D VINELAND:** mixed agriculture and forest
- **E AGRICULTURAL BELT:** extensive farmland with small woodlots and some urban development
- **F URBAN AND INDUSTRIAL ZONE:** areas of intensive land use
- **G PIEDMONT PLAIN:** mixed cropland and urban land with scattered forested traprock ridges
- **H HUNTERDON PLATEAU:** curvilinear forested ridges and cleared valleys
- **I UPPER DELAWARE RIDGE AND TERRACE:** rolling terrain with forest and agricultural use
- **J KITTATINNY MOUNTAIN:** steep series of forested ridges with low intensity land use
- **K KITTATINNY VALLEY:** rolling topography with forested ridges, cleared valleys (agricultural use), and numerous small lakes
- **L HIGHLANDS:** rugged, partially forested area with numerous lakes
- **M WASHINGTON:** level valley (rural land use) enclosed by Highlands Ecozone
- **N PASSAIC BASIN/WACHUNG MOUNTAINS:** forest cover and urban land use in a level river basin ringed by forested, traprock ridges
- **O RIDGEWOOD:** urban land use and forest cover

Scale in Miles

0 10 20 30 40

N

Earth Satellite Corporation
1747 Pennsylvania Ave., N.W.
Washington, D.C. 20006



This photomap produced from a NASA ERTS-1 mosaic of MSS band 5 taken on October 10, 1972

FIGURE 14

NEW JERSEY COASTAL AREA

NEW JERSEY COASTAL AREA

Let's protect our earth

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

The Legislature finds and declares that New Jersey's bays, harbors, sounds, wetlands, inlets, the tidal portions of fresh, saline, or partially saline streams and tributaries and their adjoining upland fastland drainage area nets, channels, estuaries, barrier beaches, near shore waters, and intertidal areas together constitute an exceptional, unique, irreplaceable, and delicately balanced physical, chemical, and biologically acting and interacting natural environmental resource called the coastal area, that certain portions of the coastal area are now suffering serious adverse environmental effects resulting from existing facility activity impacts that would preclude or tend to preclude those multiple uses which support diversity and are in the best long-term social, economic, aesthetic, and recreational interests of all people of the State; and that, therefore, it is in the interest of the people of the State that all of the coastal area should be dedicated to those kinds of land mix uses which promote the public health, safety, and welfare, protect public and private property, and are reasonably consistent and compatible with the natural laws governing the physical, chemical, and biological environment of the coastal area.

N

SCALE IN MILES

0 10 20 30 40

EARTH SATELLITE CORPORATION

GEOSCIENCES AND ENVIRONMENTAL APPLICATIONS DIV. WASHINGTON, D.C.

36a

MSS band 7 was used for the coastal area and MSS band 5 was used for the remainder of the State. This product was instrumental in the passage of new coastal legislation, "The Coastal Area Facility Review Act", establishing the state's regulatory control over approximately 20% of the state. It was distributed to and used by State Legislators during their deliberations on the Act.

4.1.4 Coastal Wetlands Map

The ability to conduct general wetlands delineation was assessed using a 1:1,000,000 scale ERTS color composite and an enlarged 1:60,000 mosaic of Band 5 (1079-15133, October 10, 1972). Manual Analysis of this and other ERTS data indicate that large wetlands areas are clearly imaged.

Detailed interpretation indicates that at least two wetland species (Spartina alterniflora and Spartina patens) can be distinquished within New Jersey's marshland areas. False color enhancement on the I^2S Addcol improved species discrimination. In the Beach Haven West area, large stands of Spartina alterniflora were distinquished from stands of Spartina patens.

The upper wetland boundary was located successfully[4/], and changes (reductions) in total wetland area resulting from

4/ The pink to reddish tonal signatures of the wetland vegetation, the position of the vegetation between barrier beaches and the mainland, and along tidal streams, all aided in the identification and separation of wetland from upland areas. The tonal and textural signatures of wetland vegetation were considerably different from those of upland plant species and the boundary was drawn along a distinct tonal and textural break. Along the Delaware River, tonal signatures indicative of wetland species could be identified along stream channels; these signatures were more difficult to identify than those seen along the coast.

development were observed. Such changes could be monitored annually if the areas were of sufficient size. ERTS-1 color composites (1:1,000,000) and a mosaic of MSS Band 7 (1:500,000) were used to delineate an upper wetland boundary (Figure 15) for coastal New Jersey.

4.2 Specific Problem Areas

Several resource management problem areas were identified by the State as needing intensive analysis. The following four were selected as being the most important in terms of both environmental concern and economics:

- Offshore Waste Disposal
- Change Detection within the Coastal Zone
- Ocean Outfall Placement
- Shore Protection.

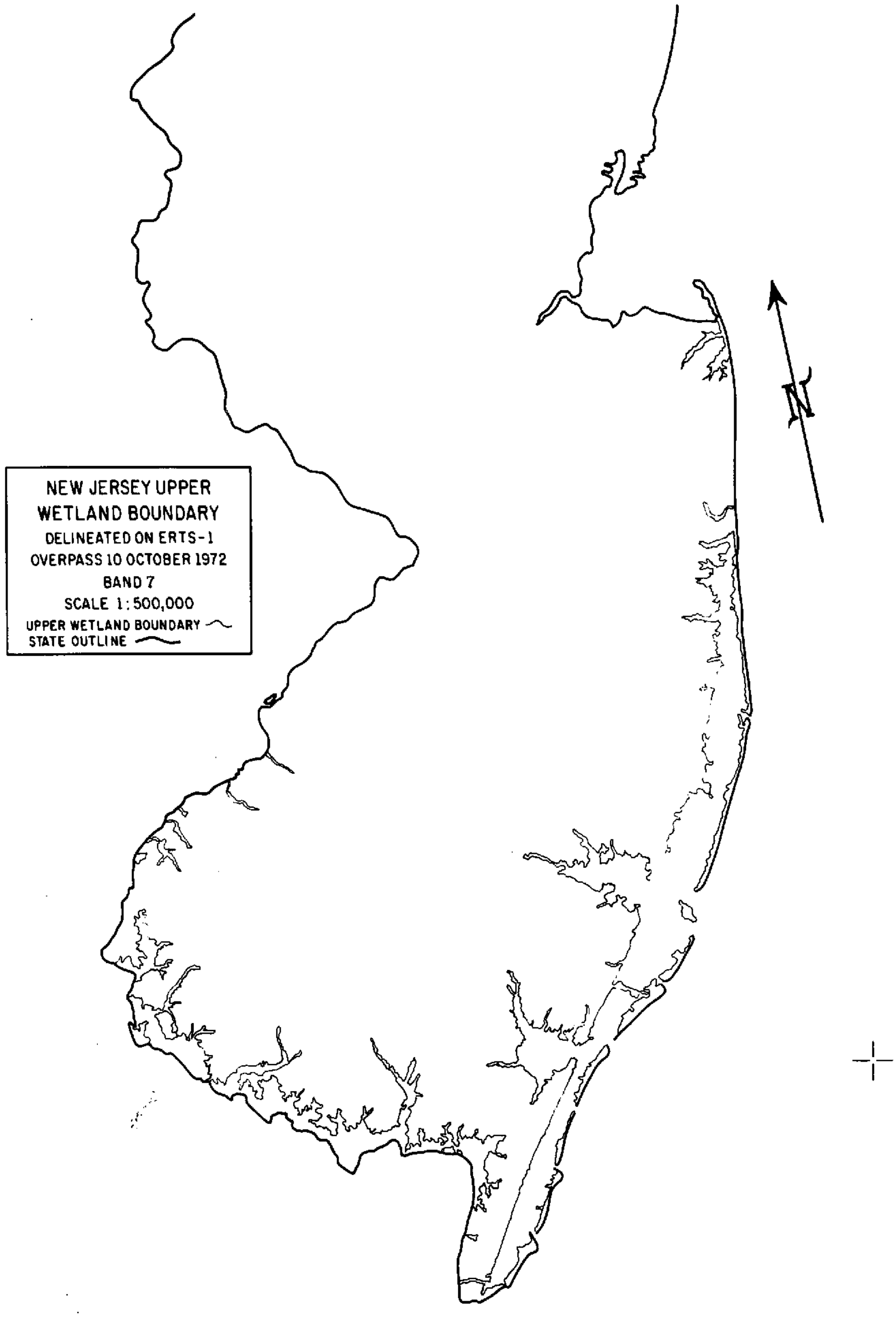
These problem areas, in which the most detailed analysis took place, were also selected because of the State's need for immediate data in order to make effective management decisions involving millions of dollars of State expenditures over the next several years.

4.2.1 Offshore Waste Disposal

New Jersey borders one of the largest offshore waste disposal sites in the world, the New York Bight. For over 40 years this area has been used as a sink for domestic and industrial wastes without an environmental monitoring program to document and assess both the short and long-term environmental

FIGURE 15

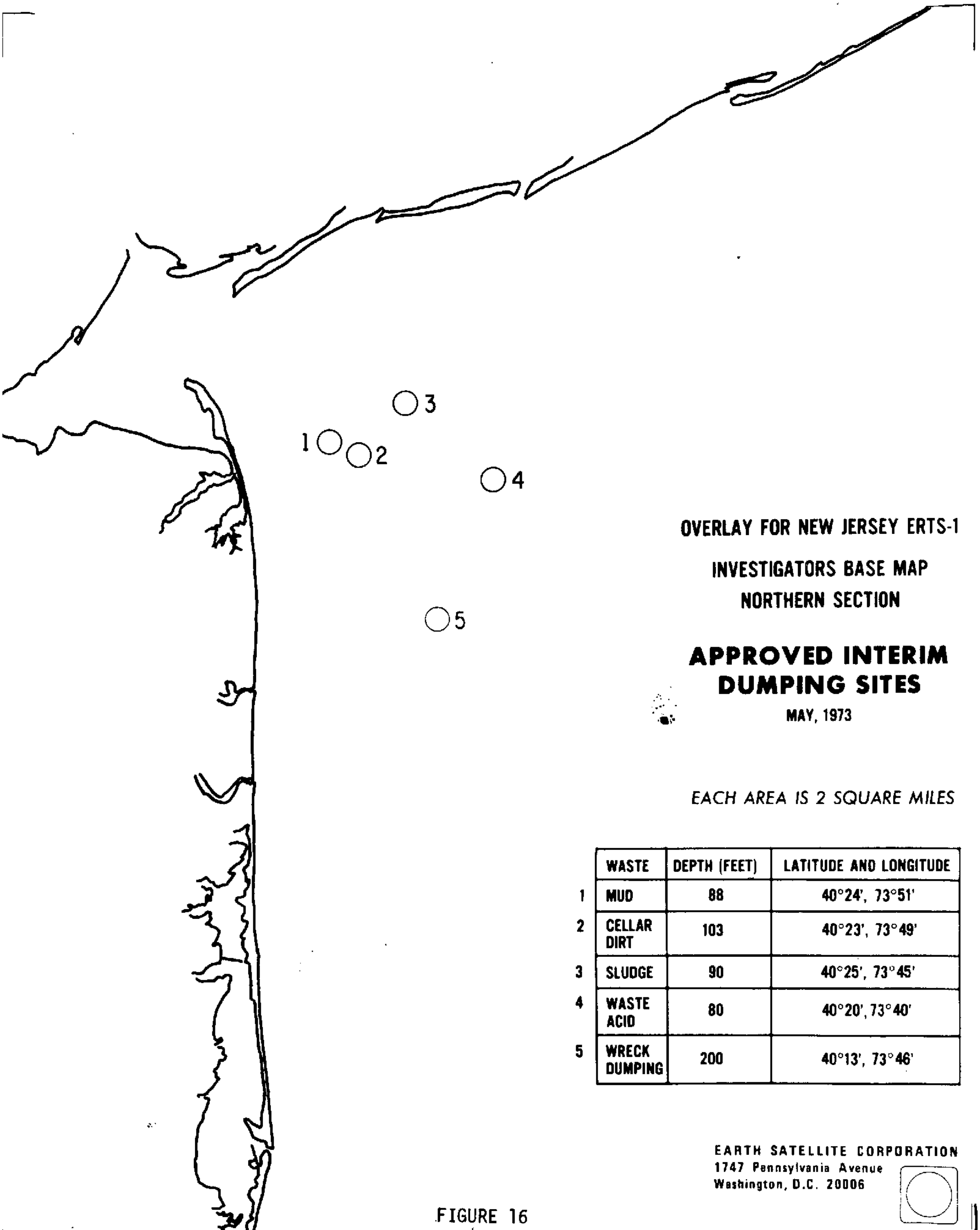
NEW JERSEY UPPER WETLAND BOUNDARY


NEW JERSEY UPPER
WETLAND BOUNDARY
DELINEATED ON ERTS-1
OVERPASS 10 OCTOBER 1972
BAND 7
SCALE 1:500,000
UPPER WETLAND BOUNDARY
STATE OUTLINE
N

effects of these disposal activities. These effects must be understood in order to determine their consequences on New Jersey's coastal resources (fish and shellfish grounds, tidal marsh, recreational areas, public health, etc.).

The "dumping grounds" lie approximately equidistant offshore both New York and New Jersey. The planning behind the original siting of the dump sites was that these waste materials once dumped over the side of a ship would sink to the bottom, flow down the Hudson Canyon and end up in the abyssal plains far out to sea. This may, in fact, happen on occasion for those materials that sink to the bottom, but most of the materials dumped in the New York Bight remain in suspension for long periods of time and are subject to the prevailing currents extant at the time of dumping. Currently, about 10 million tons of dredge spoils, construction debris, sewage sludge and industrial wastes are being disposed of within a sea surface area of 250 km^2, the annual rate of increase being about 4% (Gross, 1970). Ocean dumping operations offshore New Jersey are performed 24 hours a day, 7 days per week throughout the year except under extreme weather conditions. Present ocean dumping operations in the New York Bight are regulated by the New York District Corps of Engineers and the Environmental Protection Agency which issue permits for dumping at specific ocean locations, depending upon the material to be dumped (Figure 16).

There is no clear understanding of the fate and pathways by which waste materials pass through marine ecosystems nor are there any effective monitoring systems in existence.



OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

APPROVED INTERIM DUMPING SITES

MAY, 1973

EACH AREA IS 2 SQUARE MILES

	WASTE	DEPTH (FEET)	LATITUDE AND LONGITUDE
1	MUD	88	40°24', 73°51'
2	CELLAR DIRT	103	40°23', 73°49'
3	SLUDGE	90	40°25', 73°45'
4	WASTE ACID	80	40°20', 73°40'
5	WRECK DUMPING	200	40°13', 73°46'

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FIGURE 16

The investigators recognized that no national monitoring system was operating and that ERTS could provide the tool necessary to accomplish the task.

The objectives of this phase of the investigation were to monitor on a routine basis the ocean dumping operations offshore New Jersey, to determine the direction of drift, and to document dispersion characteristics. The State of New Jersey must understand the effects of these dumping operations on their limited coastal resources. Routine analysis of dumping operations during 1973-74 was the first attempt to regularly monitor the dumping sites and the dispersion characteristics of the surrounding waters.

Five dumping sites were studied using ERTS imagery:

- Acid Waste Dumping Ground
- Sewer Sludge Dumping Ground
- Cellar Dirt Dumping Ground
- Mud and One Man Stone Dumping Ground
- Wreck Dumping Ground

Offshore waste disposal overlays were routinely prepared (Figure 17) for each orbit[5/]; the apparent drift direction of

5/ The waste materials overlays (Figure 17) routinely delivered to NJDEP were prepared by using the Bausch and Lomb Zoom Transfer Scope (ZTS). The ZTS enabled the operator to view two documents, such as a photo and a map in superposition. In this case, the image was a 70mm ERTS-1 transparency of the New York Bight Area, and the base map was a 1:250,000 ERTS-photomap of the same area produced from the January 25, 1973 ERTS-1 overpass. ERTS-1 transparencies for each overpass were registered with the base map according to prominent landforms by using the magnification and field rotation controls on the ZTS. After the image and map were registered, an overlay of tracing paper was placed on the base map, and registration marks were made on the overlay. By alternately increasing and decreasing the illumination of the photo and map, the outline of a waste dump was traced directly onto the overlay.

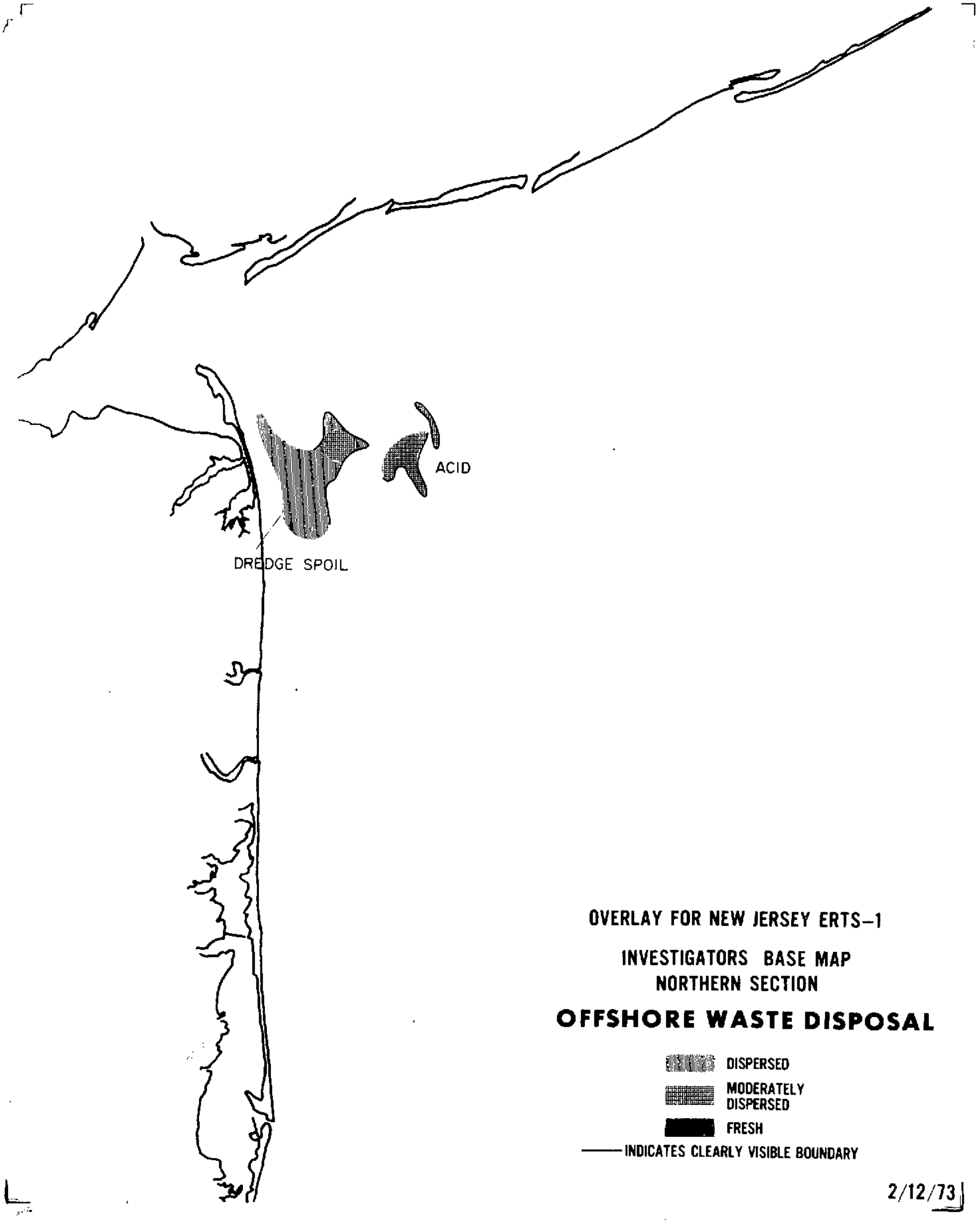

ACID
DREDGE SPOIL
OVERLAY FOR NEW JERSEY ERTS-1
INVESTIGATORS BASE MAP
NORTHERN SECTION
OFFSHORE WASTE DISPOSAL
DISPERSED
MODERATELY
DISPERSED
FRESH
INDICATES CLEARLY VISIBLE BOUNDARY
2/12/73

FIGURE 17

the dump and its geographical extent were delineated, and its dispersion characteristics were monitored. These data provided NJDEP with an introductory environmental monitoring program which would serve to document and assess both the short and long term environmental effects of ocean dumping.

In the analysis of ERTS imagery, dumps were classified as either fresh, moderately dispersed, or well dispersed. The preponderance of dumps delineated during this investigation were acid-iron waste and dredge spoil. The discharge of acid-iron waste can usually be recognized by its characteristic hairpin shaped pattern (Figure 18). Surface truth verification of the dumping operations were carried out by low-flying aircraft and boats. The acid wastes are characterized by an orange-brown color at the surface (Figure 19) with considerable flocculation at its boundaries. The waste material consists of a sulfuric acid residue ($\approx$ 10%) containing soluble iron (3%, metallic salts and insoluble material such as silica and undissolved titanium dioxide).

The dredge spoils (Figure 20) which are heavily laden with particulate matter cause an almost instantaneous build-up of turbidity within the water column as they are released. Gross (1969) has reported that the volumes of dredge spoils and other sediment-like wastes (construction and demolition debris) disposed of in Long Island Sound and in the New York Bight represent the largest single source of sediment entering directly into the Atlantic Ocean from North America.

FIGURE 18. THIS MSS BAND 5 IMAGE TAKEN 16 AUGUST 1972 (1024-15071-5) CLEARLY ILLUSTRATES THE METHOD OF DUMPING THE HIGHLY REFLECTIVE ACID-IRON WASTE. THE BARGE DISCHARGES THE WASTE WHILE UNDERWAY AND WHEN HALF THE LOAD HAS BEEN DISCHARGED IT TURNS AROUND, DUMPING THE REMAINING LOAD. THIS PROCEDURE RESULTS IN THE CHARACTERISTIC HAIR-PIN PATTERN SEEN IN THE CENTER OF THIS IMAGE.

FIGURE 19. ACID-IRON WASTE AS SEEN FROM A HELICOPTER APPROXIMATELY FOUR HOURS AFTER DISCHARGE. THERE IS CONSIDERABLE FLOCCULATION AT THE SURFACE WITH PRECIPITATE BOUNDARIES FORMING BETWEEN THE DUMP AND THE SURROUNDING WATERS. THE LIQUID WASTE IS LESS DENSE THAN THE SURROUNDING WATERS AND REMAINS NEAR SURFACE FOR A CONSIDERABLE LENGTH OF TIME.

FIGURE 20. DREDGE SPOIL DUMPINGS, WHICH RANK FIRST IN BOTH TONNAGE AND COST OF ALL OCEAN DUMPED MATERIALS WERE LESS OFTEN IMAGED BY ERTS-1 THAN THE ACID WASTE DUMPS. DREDGE SPOIL DUMP SITES WERE GENERALLY FOUND CLOSER TO THE NEW JERSEY SHORE AND WERE GENERALLY LESS REFLECTIVE. NASA ERTS 1061-15125-5.

Sewage sludge, another waste disposed of in the New York Bight, is generally about 3-10% solids by weight and is much less reflective than acid-iron wastes and dredge spoils. No verifiable dump of sewage sludge was interpreted during the ERTS analysis. This was unfortunate since the sewage sludge disposal probably has the most adverse effects on the nearshore marine environment. All studies indicate that sewage sludge in large concentrations, as in the New York Bight, where approximately 4.0 million tons/year are dumped, destroys the marine habitat in the immediate vicinity of the sludge field; that the sludge drifts slowly along the bottom with the extant current conditions; that coliform and related toxic substances are within a radius of 5 to 10 or more miles of the site; and that the toxic substances and coliform bacterial associated with the sludge are concentrated in bottom sediments. Certainly more work is needed on the quantitative discrimination of dumped materials and their environmental effects.

Waste dumps have spectral signatures that differ from the surrounding waters depending upon the type of dump and the amount of dispersion that has occurred from the time of the overpass. The manual analysis techniques for dumped material discrimination was based on the lower reflectance levels of the dredge spoils from those of the acid-iron waste and the different approved dumping locations. Each dump was descriptively classified as either fresh, moderately dispersed, or dispersed, depending upon the average photographic density of the dump site. Multiple dumps in various stages of dispersion were apparent on several dates and often several levels of dispersion within one dump were visible. In these cases, each density or dispersion level was identified using different map symbols. With multiple density levels or very faint but detectable waste dumps, it was often difficult to delineate the perimeter of the dump area on one 70mm frame of a single MSS band. Dump sites were more easily located on positive MSS band 5 imagery, but for well dispersed multiple dumps, the negatives of MSS bands 4 and 5 were most useful.

During ERTS data analysis, actual dumps did not always coincide with designated and approved dumping sites for different waste materials. The results of the ERTS offshore waste analysis can be found in Table 2 where a listing of imaged dumps, disposed materials, locations, and total area covered by each dump are recorded. ERTS-1 has proven to be a valuable means of monitoring compliance with ocean waste disposal regulations in the New York Bight area. More frequent coverage coupled with a position and time location "Black Box" on each barge would provide a very effective means of monitoring and enforcing existing ocean dumping regulations.

The predominant dispersion and movement of relict (imaged) dumps has been found to be southwest towards the New Jersey Shoreline. The dump site overlay products have provided useful information for the establishment of water quality sampling criteria applicable to the disposal of waste materials and for identifying pollution problem areas that require further investigation by NJDEP or EPA personnel. Figure 21

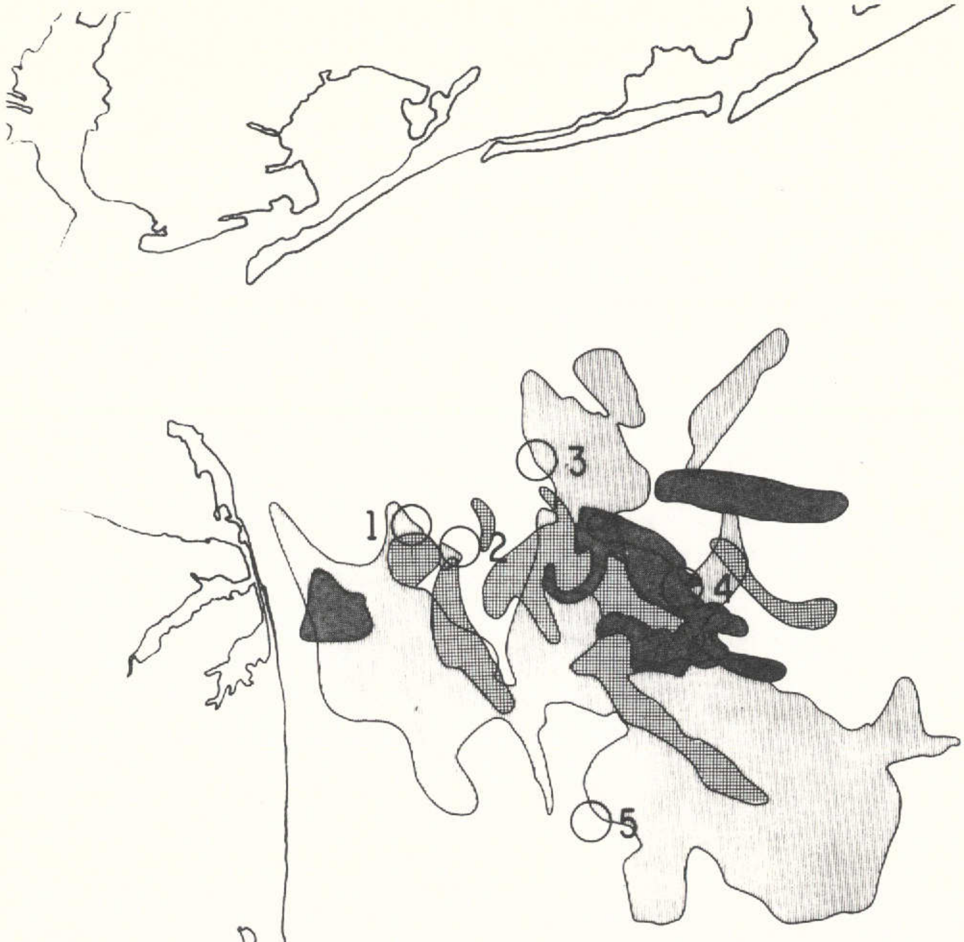
TABLE 2

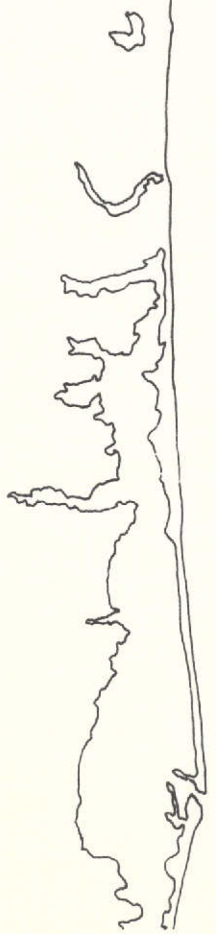
OFFSHORE WASTE DISPOSAL

ERTS MONITOR

Overpass Date	Waste Classification	Dispersion Extent	Aerial Extent (Sq. Mi.)*	Distance From Nearest Shore (Statute Mi.)
8/16/72	Acid	Fresh/Dispersed	6.9	10 NY/NJ
9/22/72	Acid/Dredge	Fresh/Moderate/ Dispersed	28.5	1 NJ
12/2/72	Acid	Fresh	10.2	14 NY
1/25/73	Acid	Moderate/Dispersed	20.2	16 NJ
2/12/73		Moderate/Dispersed	36.3	1 NJ
3/2/73	Acid	Fresh/Moderate	5.6	12 NJ
3/20/73	Acid	Fresh	3.0	14 NJ
4/7/73	Acid	Fresh/Moderate	16.5	12 NJ
5/13/73	Acid	Fresh/Moderate/ Dispersed	40.2	12 NJ
5/31/73	Acid	Dispersed	78.6	11 NJ
7/6/73	Acid	Fresh/Moderate	8.6	9 NJ
7/24/73	Acid	Moderate/Dispersed	37.8	8 NY
8/29/73	Acid	Dispersed	34.0	9 NJ

* Approved Interim Dumping Sites as set forth by the Environmental Protection Agency, Federal Register, May 16, 1973. Approved dumping grounds cover an area of 2 square miles each for both dredge and waste acid disposal.





OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP

NORTHERN SECTION

APPROVED INTERIM DUMPING SITES

MAY, 1973

EACH AREA IS 2 SQUARE MILES

	WASTE	DEPTH (FEET)	LATITUDE AND LONGITUDE
1	MUD	88	40°24', 73°51'
2	CELLAR DIRT	103	40°23', 73°49'
3	SLUDGE	90	40°25', 73°45'
4	WASTE ACID	80	40°20', 73°40'
5	WRECK DUMPING	200	40°13', 73°46'

OFFSHORE WASTE DISPOSAL

DISPERSED

MODERATELY DISPERSED

FRESH

——— INDICATES CLEARLY VISIBLE BOUNDARY

COMPOSITE OF 14 DUMPS FROM 8/16/72 TO 8/9/73

EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006

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FIGURE 21

COMPOSITE DUMP OVERLAY

represents the results of 12 months analysis for delineation of waste materials. As can be seen the actual dumping activities (and dispersion) cover a very large area whereas the dumping sites themselves are relatively small. The dispersion of the waste materials was initially designated by EPA in the proposed rulemaking to be "such that within 300 meters of the dump site the waste materials should disperse to the level of the surrounding waters." However, in the final rulemaking EPA requires that "after reasonable allowance for initial mixing in the mixing zone," (the concentration of a waste material) "will not exceed 0.01 of a concentration shown to be toxic to appropriate sensitive marine organisms in a 96-hour bioassay." (See Errata Sheet)

4.2.2 Development/Ecological Change Detection

In 1973, New Jersey passed its Coastal Area Facility Review Act which placed some 1,380 square miles of coastal land under the jurisdiction of its Department of Environmental Protection. The Act requires prior approval from NJDEP for nearly any major development within the coastal zone. An environmental impact statement describing in detail the proposed alteration and its potential environmental effects must be filed with (and approved by) NJDEP before any dredging, filling, clearing, erecting of structures, or altering of the landscape may begin.

Effective regulation under the Act requires a monitoring system. Dredging and filling of coastal wetlands and nearby upland areas occurs randomly in isolated and often unobserved locations. The destruction attendant to rapid clandestine dredging can be diminshed only by prompt detection and reporting to the appropriate State agencies.

Because the State has so strongly controlled wetlands development (Wetlands Act of 1970), much new development has shifted to upland areas. Pressure on upland areas has a direct bearing on the productivity of wetland and estuarine areas as well as the suitability of coastal and estuarine waters for wildlife and recreational use, and thus is deserving of strictly enforced regulation, as under the Coastal Area Facility Review Act.

Monitoring and enforcement of these Acts is the responsibility of the Division of Marine Services which must inspect all dredging and filling operations in the wetlands and all clearing and development activities in the adjacent upland. The Division employs numerous inspectors, the marine police, helicopters and light aircraft for the difficult monitoring required. The Division relies heavily upon citizen reports. Aerial photography of the entire coastal zone on a two-week frequency would provide the necessary data but certainly would not be cost effective. The task of monitoring change within large land areas, over extended periods of time (years) with a high frequency of coverage (days) was judged by the investigators to be a task which lent itself quite naturally to accomplishment from ERTS.

Prior to the advent of the present ERTS/remote sensing technology, ground/helicopter monitoring was either impossible, haphazard, or too costly. With the present ERTS-1 satellite coverage every 18 days, the monitoring system is limited only by such uncontrollable factors as weather, and can be executed regularly at a nominal cost with the development of automatic data processing techniques.

A shared satellite monitoring system appeared to be the only viable and cost effective solution. The investigators judged that ERTs could provide repetitive data which would be more reliable than data obtained by conventional techniques. A repetitive change detection system with high resolution and frequency was needed to aid the field inspectors in their enforcement activities. Such a demonstration in New Jersey, might encourage other coastal states to adopt similar ERTS-based procedures.

Five interpretation techniques were investigated as possible means of comparing successive ERTS images to locate any alteration of the landscape (cultural, ecological, agricultural). The investigators judged that reflectance differences between the altered area and the background would have to be 20% to 30% on the ground to be sensed consistently at satellite altitude and be approximately two hundred feet (200') square, i.e. the approximate dimension of the instantaneous field of view on the ground. The five interpretation techniques evaluated for ERTS imagery were:

(1) Manual comparison of 9" x 9" prints from successive ERTS overpasses

(2) Addcol superposition of 70mm transparancies

(3) Manual comparison of photographic enlargements at 1:125,000 scale

(4) Zoom Transfer Scope superposition

(5) Zoom stereo viewing superposition of

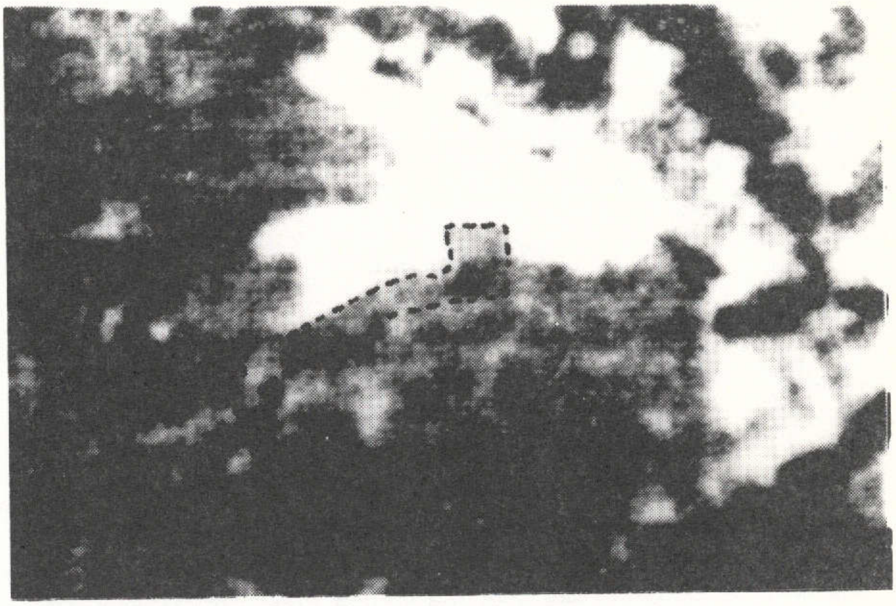
(a) 70mm chips

(b) enhanced 8" x 8" Litton prints

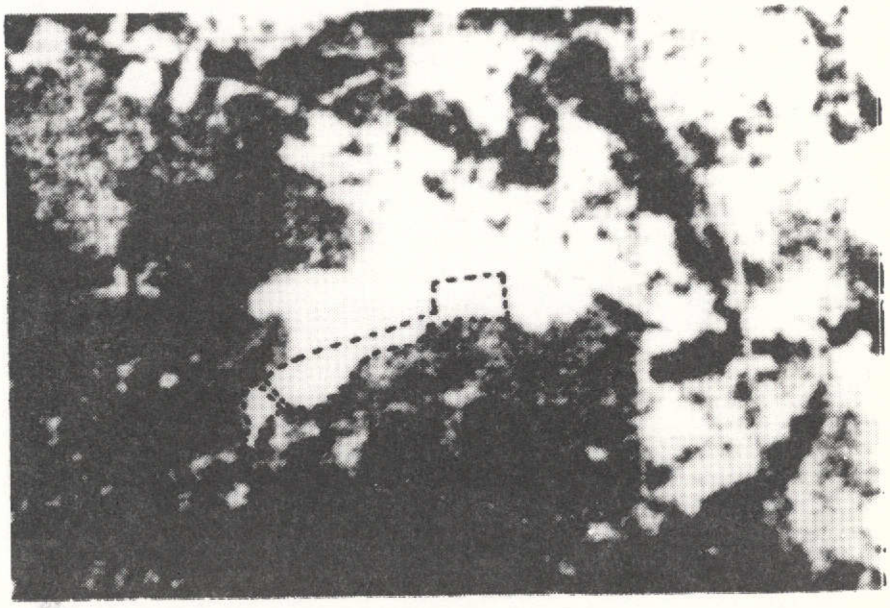
Following a period of technique exploration and evaluation, it was determined that the zoom stereo viewing technique was the most useful as it offered the most flexibility for the operator and greatest resolution. In order to further develop and refine the zoom stereo analysis technique, a quasi-operational change detection study was performed using imagery collected nine months apart. The overpass dates selected were October 10, 1972 and July 6, 1973. These dates were selected because the imagery was 95% cloud free, haze conditions were light, and enough time had elapsed to include a large number of landscape alterations.

During subsequent analysis of the two frames each interpreter compared the October 10, 1972 overpass (left eye) with the July 7, 1973 overpass (right eye), by alternately blinking the right and left eye. In a modification of this technique, the interpreter used his hand to rapidly and intermittently block the right eye image. Changes as viewed in this manner were noted as areas of darker and lighter tones flashing on and off; this technique was named the "flicker technique". ERTS reproductions (Figures 22 and 23) of these changes illustrate how this technique was applied.

A preliminary but complete interpretation of the two images was performed for the project test area and each change was located on a 1:250,000 ERTS base map. Care was taken with

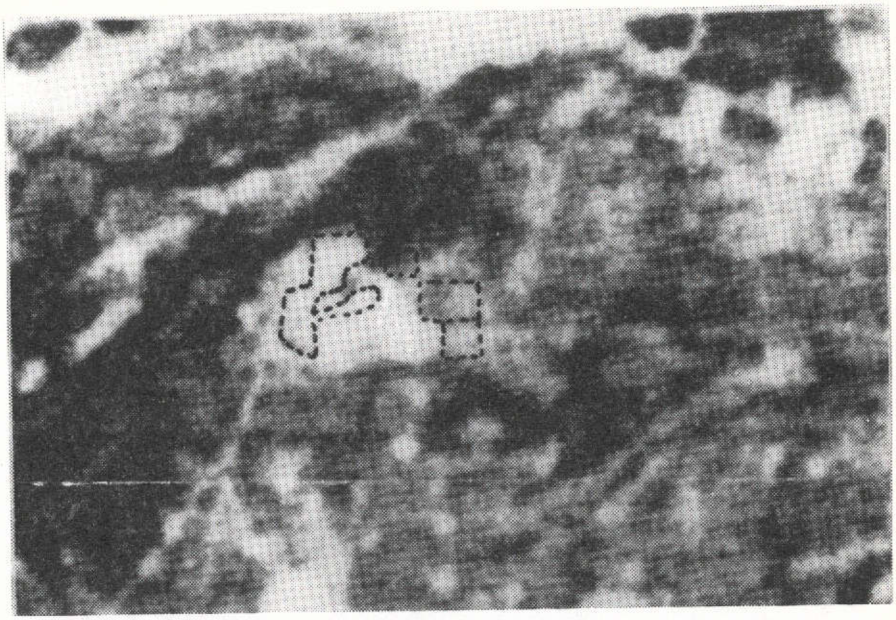


OCTOBER 10,1972

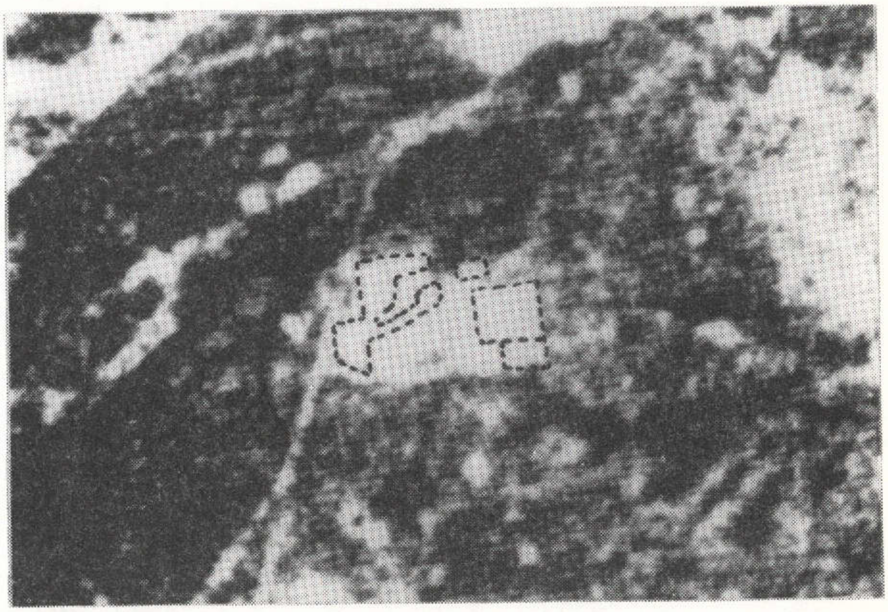


JULY 7, 1973

FIGURE 22. 1:250,000 SCALE COMPARISON OF THE TWO ERTS IMAGES ILLUSTRATING AREAS (WITHIN THE DASHED LINES) WHICH HAVE UNDERGONE DEVELOPMENT. THIS MAJOR LAND CLEARING IS LOCATED IN TOMS RIVER, NEW JERSEY.



OCTOBER 10, 1972



JULY 7, 1973

FIGURE 23. AT AN APPROXIMATE SCALE OF 1:250,000, ERTS IMAGERY IS READILY INTERPRETABLE WITH THE AID OF A 1:24,000 PHOTO-QUAD SHEETS AS REFERENCE. THESE TWO IMAGES ILLUSTRATE LAND CHANGES CAUSED BY ILMENITE SLURRY-MINING ACTIVITY.

effort to discover all differences between the two frames and to very accurately locate each change on the ERTS base map. More than 276 such changes were interpreted and were plotted on an ERTS base map. During the analysis it became evident that several levels of tonal differences were indicative of various types of landscape alterations. Large tonal differences with sharp boundaries were usually associated with land development activities such as those resulting from land clearing for road construction and house site preparation. This was always a tonal shift from dark to light. Vegetated areas imaged in dark tones before being cleared; after being cleared, the highly reflective sandy soil common to the New Jersey coastal area is exposed. Such cleared areas are rendered in light tones on ERTS imagery.

Following the in-depth analysis of the ERTS imagery and plotting of all the changes on the 1:250,000 basemap, a similar but more exacting location analysis was performed with the aid of New Jersey's 1:24,000 photo-quad sheets (based on imagery acquired during March and April 1972). The method the investigators used to transfer the changes interpreted from ERTS (at a scale of 1:250,000) onto the 1:24:000 photo-quad sheets consisted of a careful comparison of the ERTS image in the vicinity of the change to the same vicinity on the photo-quad sheet. Exact location was possible by starting from a point or points common to both the ERTS image and the photo-quad and then moving in the direction of the change to the next identifiable point. Detail such as road networks, field and woodland boundaries, water/land interfaces, streams, drainage patterns, cities, towns, lakes and major cultural features were used to locate the changes. With practice, areas 200' x 200' were interpretable, and on occasion areas less than 100' on a side were recorded (Figure 24)[6/].

Once the exact location of a change was determined on the photo-quad sheet, a delineation of the change was performed by relating the general shape of a change on ERTS to the existing land use and ecological patterns on the photo-quad. In this manner it was possible to locate the likely boundaries of the change and effect an accurate delineation. Figure 25 illustrates the delineation of a change on a photo-quad based on the ERTS interpretation as seen in Figure 22.

Following the transfer of changes as detected from ERTS onto the photo-quad sheets a field verification survey was performed in order to determine the accuracy of the change detection system. A light reconnaissance aircraft was used for these verification flights. Both the pilot and the observer-photographer had performed the ERTS interpretation/delineation and were thus familiar with what information was required from the field exercises. Low level flights were conducted within the coastal area and as each change site was verified, the observer recorded his observations as to type of change activity taking place and type of surrounding area (i.e. forested, agricultural, wetland). In addition an oblique photograph was

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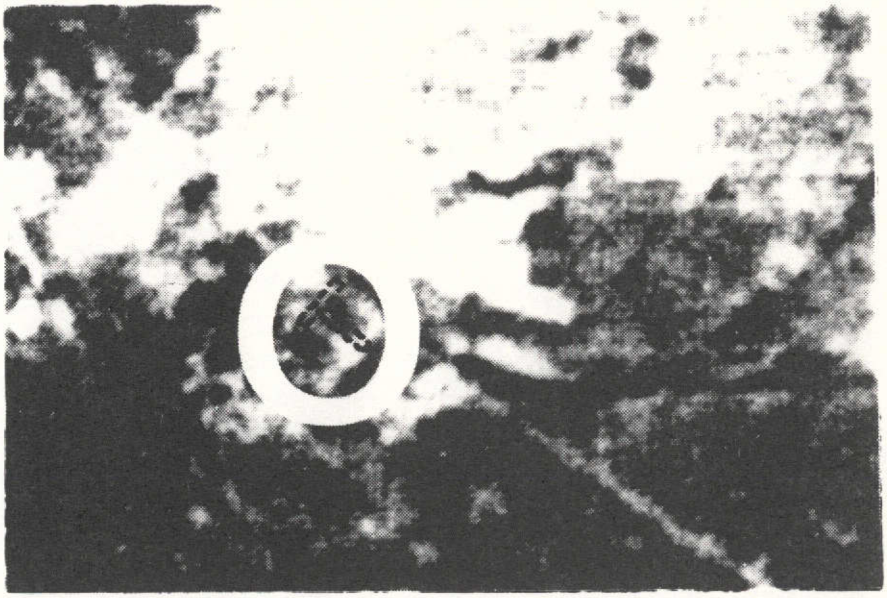
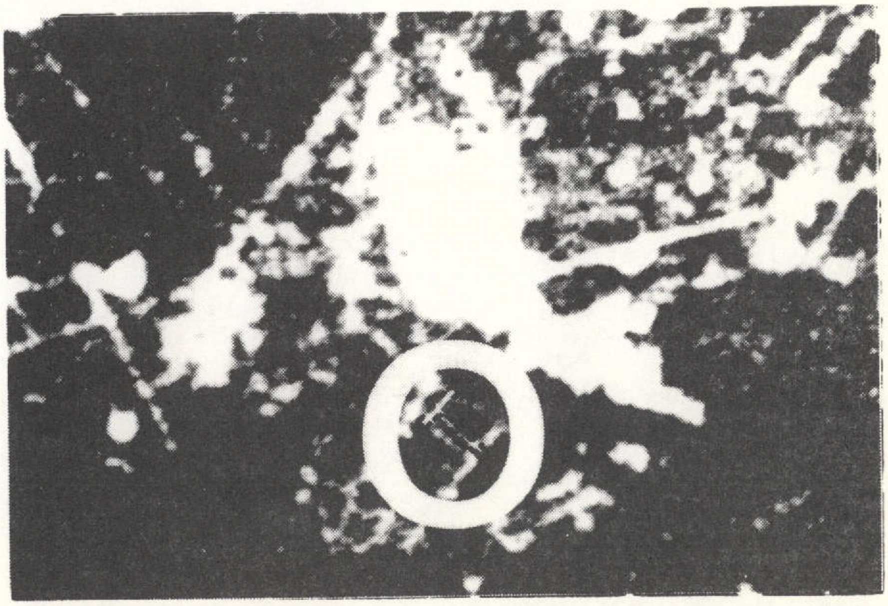
6/ For areas with high contrast ratios between the subject and background, it is theoretically possible that ERTS signal intensity will be responsive to ground areas as small as one hundred feet on a side (100' x 100'). The ERTS Data Users Handbook shows the modulation transfer function curve asymptotically approaching the x-axis at a limiting resolution of one hundred feet (100'). Interpretation of ERTS imagery during this study has confirmed the theoretical ultimate response. Linear objects running parallel, oblique, and perpendicular to the scan lines have been imaged, interpreted, and accurately located on the photo sheets.

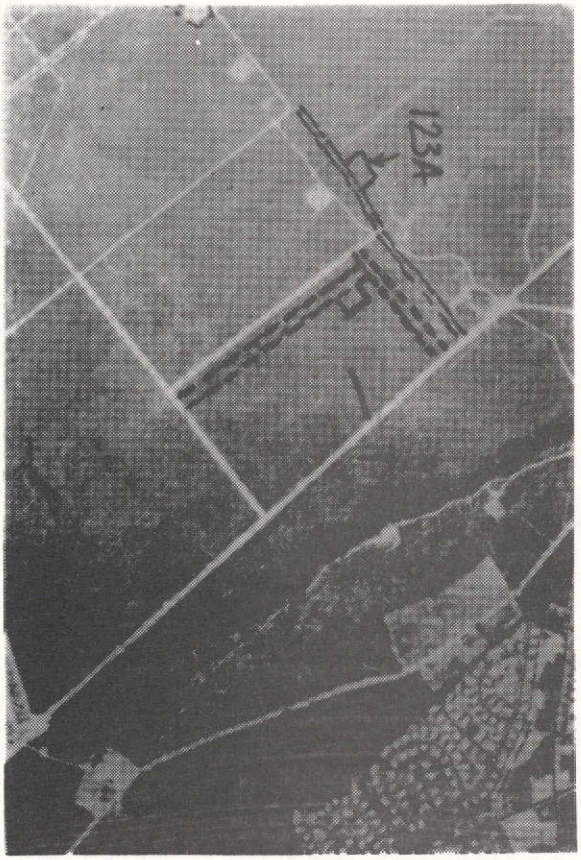
FIGURE 24. Minimum change detection capability using ERTS (A) and (B). These two frames illustrate a minimum resolution change enlarged to a scale of 1:250,000, (C) shows the delineation of this 100' road under construction in the Pine Barrens near Tom's River, (D) an aerial oblique photograph used to verify the existence and relative size of this high contrast cultural feature.



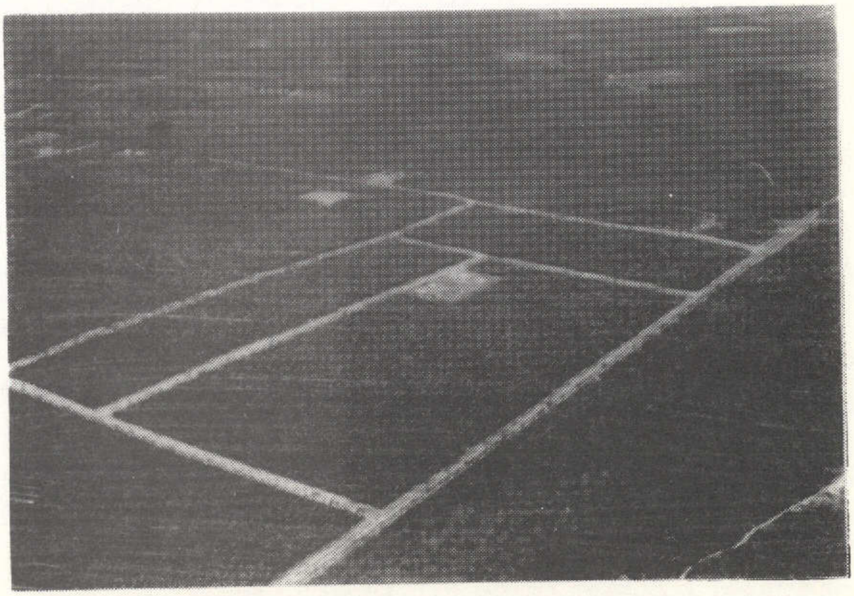
(A)
OCTOBER 10, 1972



(B)
JULY 7, 1973



(C)



(D)

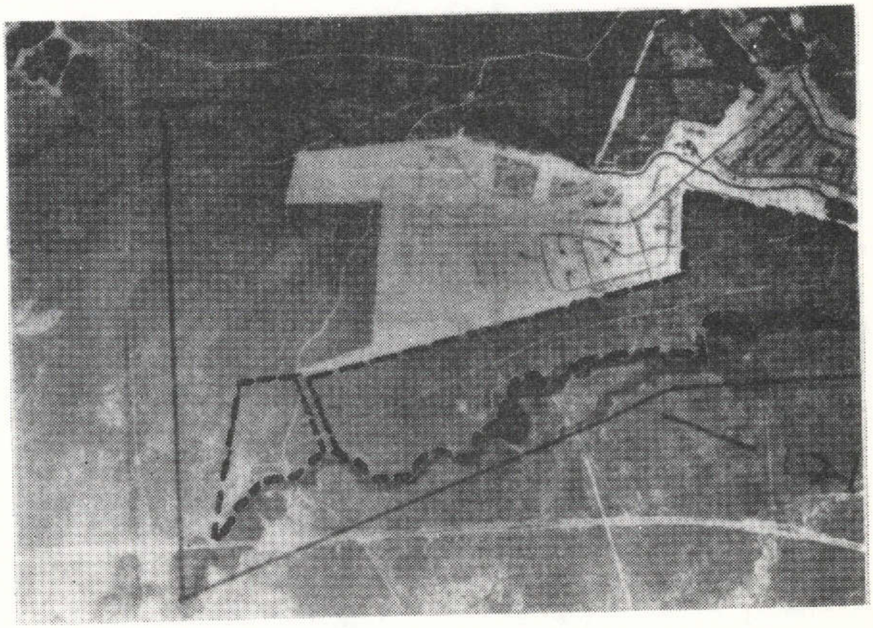
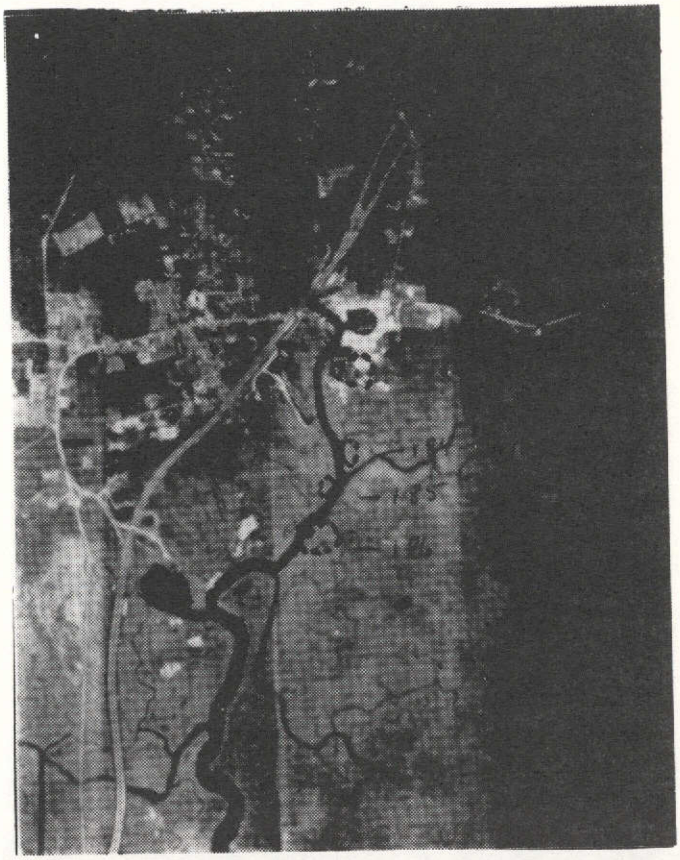


FIGURE 25. FROM INTERPRETATION OF ERTS IMAGES SHOWN IN FIGURE22, DELINEATION OF ADDITIONAL LAND CLEARING UNDERTAKEN BY THE DEVELOPER BETWEEN THE TWO OVERPASSES WAS ACCOMPLISHED. BY COMPARING THE TWO ERTS IMAGES WITH THE PHOTO-QUAD SHEET IT IS EVIDENT THAT ADDITIONAL LAND HAD BEEN CLEARED ALONG THE SOUTHERN EDGE OF THE EXISTING DEVELOPMENT TO THE SMALL CREEK WHICH IS EITHER THE PROPERTY BOUNDARY OR THE LIMIT OF DEVELOPABLE LAND. THIS ILLUSTRATES THE INFERENCE INTERPRETATION PROCEDURE POSSIBLE BY SUPPLEMENTING ERTS IMAGERY WITH LARGER SCALE PHOTOGRAPHY.

taken to record the exact location and extent of activity found at the time of field data collection. In instances where no change-producing activity was evident, several alternatives were considered as to what might have caused the change imaged by ERTS. In some cases it was concluded that subtle tonal variations were probably caused by seasonal vegetative differences or tidal differences between overpasses. In cases where drastic tonal differences were recorded on ERTS but no change was found in the field, clouds were considered to be the likely cause. As the field effort progressed, landscape alterations were observed that were either (a) not present at the time of the ERTS overpass, or (b) were present but not imaged. These alteration sites where photographed and located on photo-quad sheets so that analyses of imagery subsequent to the field work could be performed. Two types of errors were possible: (a) errors of commission, a change was interpreted when, in fact, none really existed (Figure 26), and (b) errors of omission (Figure 27), a change really existed but it either was not imaged on ERTS or was missed during the interpretation. To tabulate the results of the change detection system analysis, a tally sheet was designed (Table 3) and three classification keys (Appendix A) were set up. The tally sheet presents an initial tabulation of results for several change sites. The change site number is listed in the first column and a brief classification description of the area surrounding the change site is listed in coded form in the next column. Broad land type and land use classification categories were used to describe the general area surrounding a change.



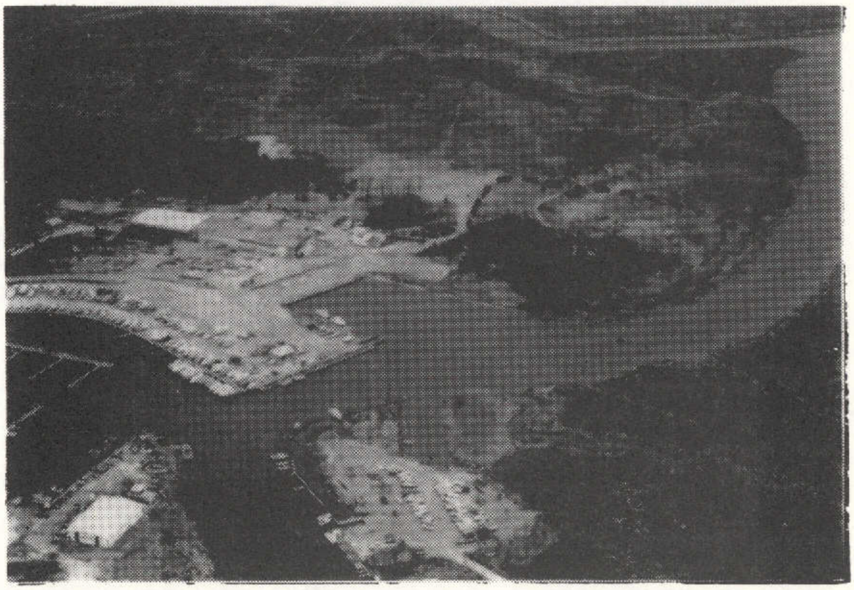
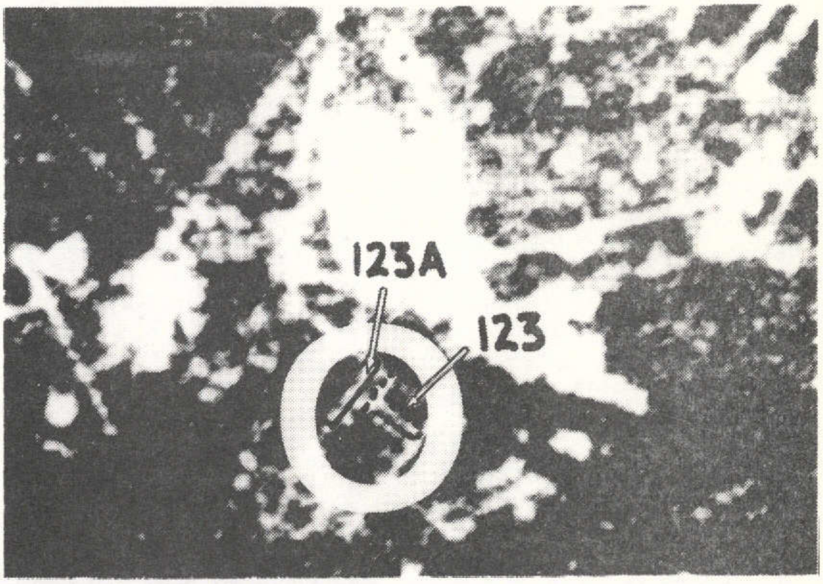
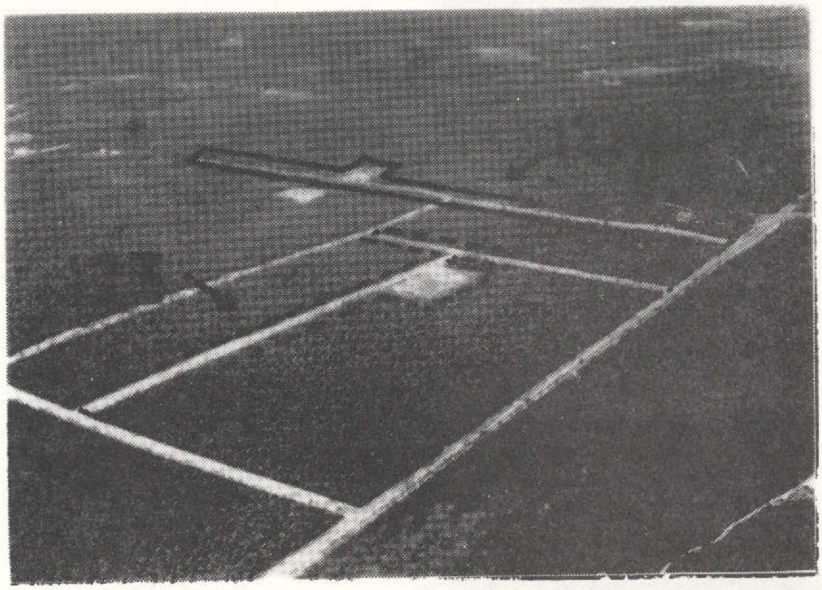


FIGURE 26. DREDGE SPOIL DEPOSITION PILES WERE INTERPRETED FROM ERTS AND DELINEATED ON THE PHOTO-QUAD SHEET SHOWN IN THE TOP PHOTOGRAPH. AERIAL FIELD INSPECTION(BOTTOM PHOTO) INDICATED NO SUCH PILES. IT IS SUSPECTED THAT THIS ERROR OF COMMISSION WAS CAUSED BY SEVERAL STRAY CUMULUS CLOUDS BECAUSE THERE WAS A HIGH CONTRAST RATIO BETWEEN THE SUSPECTED CHANGE AND THE BACKGROUND. VEGETATIVE AND TIDAL DIFFERENCES WOULD HAVE IMAGED IN MORE SUBTLE TONAL VARIATIONS.

FIGURE 27. Error of Ommission. Photograph (A) indicates the ERTS detected change in the dashed lines. Upon field inspection, Photograph (B), the change was in fact verified. However, a second parallel road was observed that was not interpreted on the ERTS image. Upon re-examination of the ERTS image, the change was in fact imaged (solid line delineation) but was not interpreted. Photograph (C) illustrates this error of ommission. Site #123 was interpreted but site #123A was not detected by the interpreter even though both sites were imaged.

(A)





(B)

(C)

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TABLE 3

TALLY SHEET OF RESULTS

CHANGE DETECTION ANALYSIS

SITE #	AREA DESCRIPTOR	CHANGE TYPE	ERTS DETECTION CONFIRMED Yes	/DelAcc*	ERTS DETECTION UNCONFIRMED PossCause**	FIELD OBSERVED CHANGES	IMAGED ON SUBSEQUENT ERTS YES	NO	IMAGED ON ERTS INTERPRETED YES	NO
115	A,F,J	Id	X	B						
116	A,F,J,	Id	X	B						
117	A,F,J,	Id	X	A						
117A	A	Id				X	X			
118	A				b					
119	A,F	Ia	X	B						
119A	A,F	Ia				X	X			X
120	A,F	Ia	X	A						
121	A,F	Ia	X	A						
122	A,F	Ia	X	A						
122B	A,F	Ia				X	X			X
123	A,K	Iai	X	A						
123A	A,K	Iai				X	X		X	
124	A,K,F	I						X	X	
131-1	A,F,K	Ij	X	A						
131-B	A,F,K	Ij				X		X		X
131-A	A,F,K	Ij				X	X			X
145-1	A,J	Id			d(e)			X	X	
145-2	A,J	Id	X	A					X	
145-A	A,J	Id				X	X			X

* Delineation Accuracy ** Possible Cause

The third column on the tally sheet lists the type of change activity or landscape alteration that caused the difference of reflectance imaged by ERTS. There were three major categories of changes found to alter the landscape: cultural changes, ecological changes, and seasonal changes. More specific subcategories are presented so that analysis of results can be carried to several levels of detail.

Field verification of the changes as detected from ERTS imagery are recorded in columns four and five on the tally sheet. An "x" was placed in the first half of column four if the observer found an obvious landscape alteration at the site location. A three letter code was used in the second half of column four to rate the accuracy of delineation. This rating was determined by comparing the ERTS interpretation with the aerial oblique documentation photographs and with the delineations sketched in the field. The delineation accuracy was rated as either accurate, fairly accurate, or inaccurate.

Column five lists the possible or probable cause(s) for the error; i.e., that of detecting a change from ERTS but finding no confirming evidence of a change having taken place in the field.

Column six lists all the change sites discovered in the field which were not interpreted on the analyzed ERTS overpasses. An "x" was placed in column six and an alpha-numeric site number was used to differentiate these changes from those noted first on ERTS. Columns seven and eight record whether or not these change sites were imaged on subsequent ERTS overpasses.

In instances when they were not imaged on subsequent ERTS overpasses, the system is responsible for and was charged with an error of "omission" due to system limitations. Columns nine and ten were used to note whether these changes had been imaged on the original ERTS images (October 10, 1972 and July, 1973) and overlooked during the initial interpretation (error of "omission" due to interpretation).

4.2.2.1 Operational Demonstration of Change Detection

Throughout the course of the investigation the ERTS based changed detection system suffered from data acquisition delays that seriously reduced its usefulness to NJDEP. Changes interpreted from ERTS and reported to NJDEP were usually two months old and were consequently already known to the department's inspectors. Comments of "too little, too late" were attached to change detection products by the Division of Marine Services' field inspectors.

To determine whether change detection information would be valuable in a real-live situation, NJDEP petitioned NASA to supply ERTS computer compatible tapes (CCT's) as quickly as possible following clear overpasses starting in February of 1974. The arrangements were agreed upon by NASA, NJDEP, and EarthSat and on Tuesday, February 26, 1974, the weather conditions along the New Jersey Coast were clear and cold following the passage of a cold front. On Thursday, February 28, EarthSat received CCT's from NASA, processed them overnight, analyzed them for areas of possible landscape alteration on Friday, March 1, and reported results to NJDEP on Monday, March 4.

This was the first time data had been available, analyzed, and reported to NJDEP in less than one week (6 days) following an ERTS overpass.

With receipt of timely data the response from the inspectors, upon seeing a satellite image of their area rapidly enough such that they could easily recall weather conditions and the status of ongoing development activities with which they were familiar, was much more responsive. Division personnel at various levels within NJDEP had, by this time, developed a working facility with satellite imagery and other remote sensing data. Final judgement was still reserved, however, pending the success of comparative analysis of the next overpass and the actual location, delineation, and verification of land development alterations occurring within the eighteen-day interim period between overpasses.

Data from a second generally cloud-free overpass (March 15, 1974) was obtained seventeen days after the February 26, 1974 overpass. The flight lines of ERTS overpasses are such that the coastal areas of New Jersey are imaged twice every eighteen days due to the overlap between orbits on successive days. This effectively increases the odds of obtaining a clear overpass by 100%. The tapes were received on Wednesday, March 20, processed overnight and analyzed on Thursday. The results of the first rapid access change detection comparative analysis were delivered to NJDEP on Friday, March 22, 1974, exactly one week following the overpass. Numerous differences imaged within the elapsed seventeen-day time interval. Many of these differences were due to snowfall/snowmelt patterns. It was obvious, however, that the system had indeed recorded the exact conditions on the ground and that the capability to monitor changes, be they meteorological or cultural, had been demonstrated operationally.

Differentiation between meteorological and cultural changes (in this case snow from developmental alterations) was not easily accomplished and was recognized as a system limitation.

A careful comparison of the two overpasses was conducted in an area near Prospertown, New Jersey on the Roosevelt photo-quad. It was known that site preparation was underway for the construction of a safari park. The delineation of changes interpreted from comparative analysis of the two images can be seen in Figure 28.

Several factors are evident from the delineation in Figure 28:

- ERTS monitoring provided an update of the photo-quad sheet.
- ERTS monitoring has proved of value for detecting landscape differences within a short time frame, i.e., 17 days.
- ERTS monitoring of this site was used to detect change areas of four hundred feet (400') on a side.
- ERTS monitoring recorded the extent and configuration of the site preparation at two points in time for enforcement of state statutes.

Field verification of the accuracy of delineation of site preparation activities was unavailable. It is probable that some of the apparent field differences imaged by these two overpasses are differences in snowfall/snowmelt patterns

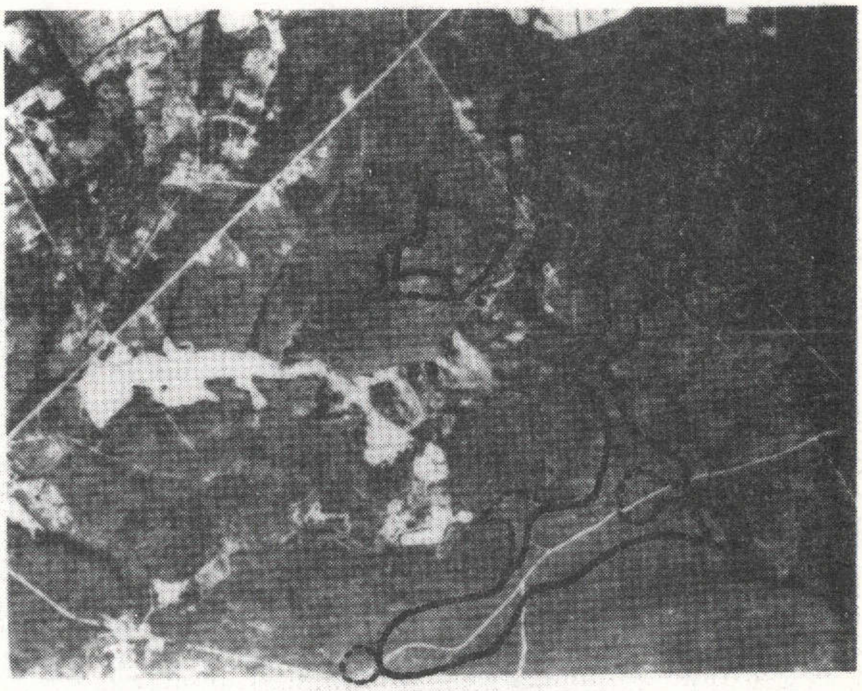


FIGURE 28. RESULTS OF A COMPARATIVE ANALYSIS OF THE TWO SUCCESSIVE ERTS OVERPASSES 17 DAYS APART ARE PRESENTED ON THIS REPRODUCTION OF A PHOTO-QUAD SHEET. THE SOLID LINE DELINEATION REPRESENTS THE CONDITIONS INTERPRETED ON THE FEBRUARY 26, 1974 OVERPASS AND THE DASHED LINE DELINEATION REPRESENTS FURTHER CHANGES INTERPRETED FROM THE MARCH 16, 1974 OVERPASS. AS CAN BE SEEN, SEVERAL AREAS WERE INTERPRETED AS HAVING UNDERGONE FURTHER DEVELOPMENTAL ACTIVITY.

between the two dates. The monitoring capability of the system is thus limited by meteorological phenomena, such as snow cover, to the extent that it is indistinguishable to the interpreter from site preparation. There may also be instances where snow cover enhances the image interpretability because it increases the contrast between wooded (vegetated) and cleared areas. In any event, a practical satellite monitoring system must involve prompt interpretation and field verification which closely follows the time of the overpass to obtain maximum advantage and to guarantee accuracy of results. If this combination is possible, satellite monitoring systems will provide useful information which is impossible or prohibitively expensive to obtain in any other manner.

4.2.3 Ocean Outfall Placement

New Jersey's coastal zone, like that of all coastal states, is subjected to the pressures of a growing population and the attendant needs for recreation in coastal waters. New Jersey must dispose of wastes produced by a growing coastal population while minimizing adverse environmental effects and economic impacts.

While sewage waste disposal has been a national problem for many years, it is only within the last decade that substantial public concern over waste disposal practices has been expressed. Numerous alternative methods for both the treatment of wastes and the movement of the effluent to the oceans are available.

One method of disposal, the direct discharge of wastes through ocean outfalls, can be less costly than others and, in many areas, creates less hazard than discharging into aquifers or estuarine areas. The efficiency of ocean outfall systems may vary significantly and is rarely confirmed after their construction. Efficiency is dependent in large part on nearshore circulation and surface dispersion in the vicinity of the outfall. Consultation with State officials and their consulting engineers revealed however that little or no systematic use has been made of nearshore circulation or surface dispersion information developed from remote sensing techniques.

The State of New Jersey has prepared and is implementing a regionalized plan for waste disposal along the Atlantic coast. Sewage from many small existing and planned drainage networks is collected, treated and discharged into the sea through one of sixteen large ocean outfalls[8/]. Strict design criteria have been set by the State of New Jersey to maintain water quality standards for bathing in the nearshore waters along the entire coast (CW-1 classification). The standards also call for secondary contact recreation (boating, sailing) out to three miles from the shore (CW-classification).

8/ An ocean outfall is a pipeline that carries and discharges waste into the ocean. The outfall pipe usually runs along the bottom and terminates with a diffuser section which divides the waste flow into small ports or jets. The discharged wastes are then subjected to the existing currents and buoyant forces of the receiving water. The waste effluent, being less dense than the surrounding sea water, will rise up through the water, mix with the ambient liquid, and finally form a waste field or plume at the surface.

Since the estimated cost of New Jersey's planned outfalls is on the order of $50 million and the beaches of New Jersey and the recreation derived thereon is the largest industry in the State (as it is for many coastal states), NJDEP required comprehensive information on the design of their ocean outfalls.

The objective of this portion of the investigation was the development of nearshore circulation information that could be integrated into NJDEP's plan for regionalized ocean outfalls. Two of these outfalls have already been built, but the designs for the remainder were still receptive to new information sources as provided by ERTS and aircraft analysis. The design of ocean outfalls for New Jersey has not relied heavily upon marine current information; rather, the dilution ratio of the effluent from the bottom to the surface has been the predominant factor considered.

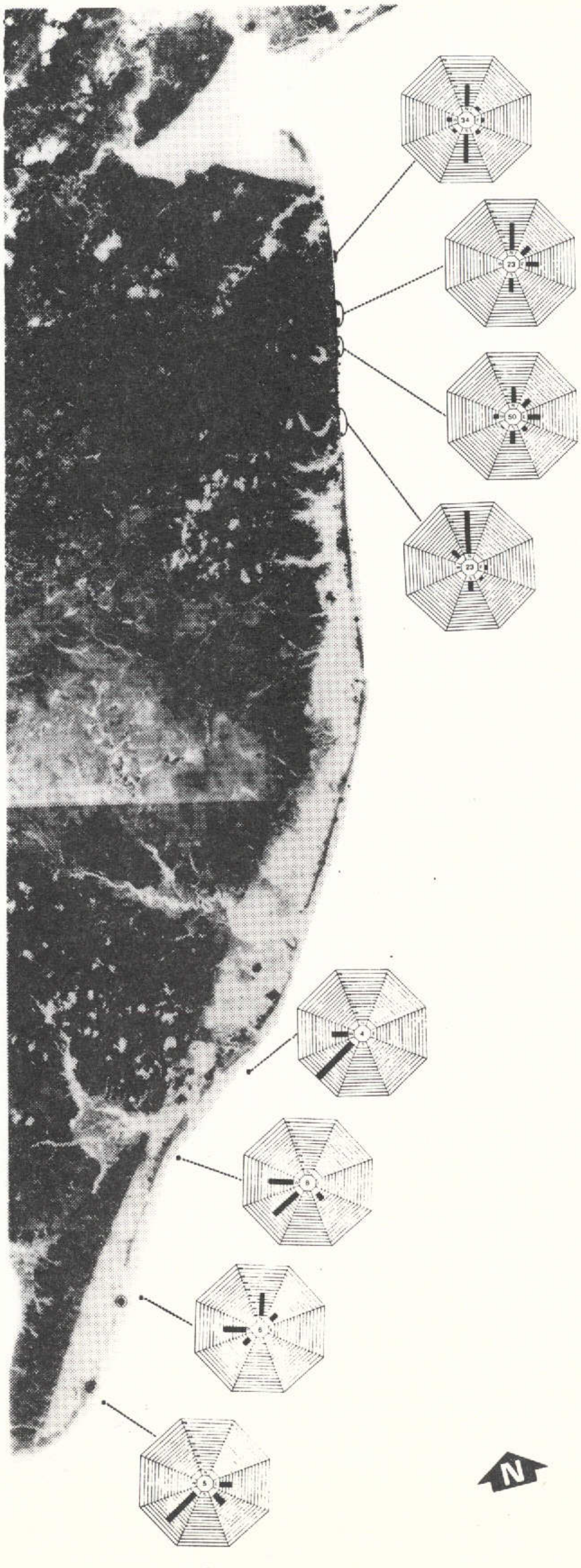
During initial NJDEP interviews, ERTS-1 information on circulation was cited repeatedly by the Division of Water Resources as the kind of input required for more effective outfall design. Several circulation products were prepared (Figures 10, 11, and 12) using existing and historical data and subsequently delivered to the State. These products were provided to develop within NJDEP an understanding of circulation and how remote sensing data might play a part in future management decisions. As ERTS-1 and aircraft data analysis proceeded, several other nearshore circulation information products were developed and delivered to the State based on these analyses.

C-2

Surface currents along the entire Atlantic coast of New Jersey were analyzed using a variety of data sources. An Outfall Planning Map (Figure 29) was prepared for NJDEP use, delineating nearshore current information at selected sites along the coast. These sites were analyzed based on two factors: the planned positions of the ocean outfalls and water mass boundary features (Figure 30), imaged from ERTS or aircraft photography, that are indicative of nearshore circulation.

Remote sensing technology is particularly applicable to nearshore circulation studies for this purpose because of naturally occurring color fronts, tide lines, foam lines, current shears, etc., which are frequently imaged along coastlines, harbors, and estuaries. These boundaries, separating water masses, are observed in and near every estuary along the Atlantic coast where river or estuarine water flushes periodically into the ocean as a result of tidal action. When these naturally occurring color fronts did not exist or where more detailed knowledge of the circulation dynamics was needed, dye tracer techniques (Figure 31) were utilized to study the complex circulation characteristics within New Jersey's nearshore zone. Both naturally occurring color fronts and dye implants were used successfully in this experiment to assess nearshore circulation dynamics using ERTS and aircraft data.

One of the first steps of this investigation was to prepare and present circulation information to the engineers who were designing and building New Jersey's ocean outfalls.



OUTFALL PLANNING MAP

NEARSHORE CURRENTS

NEW JERSEY COASTAL AREA

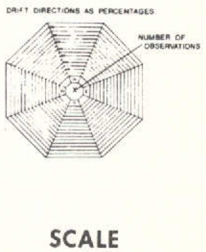
Let's protect our earth

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

THESE DATA SHOW THE PERCENT OF TIME SURFACE CURRENTS HAVE BEEN OBSERVED TO FLOW IN THE DIRECTIONS INDICATED WITHIN AN AREA JUST OUTSIDE THE LITTORAL ZONE EXTENDING TO ONE (1) MILE OFFSHORE. THESE DATA SETS WERE COMPILED FROM A COMBINATION OF INPUTS FROM SEVENTEEN (17) ORBITS OF THE EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS-1), NINETEEN (19) YEARS OF SUPPLEMENTARY AIRCRAFT PHOTOGRAPHY INCLUDING NASA SUPPORT MISSIONS, AND FROM INDEPENDENT STUDIES. THE AREAS CHOSEN FOR ANALYSIS ARE BASED ON THE PROPOSED LOCATIONS FOR NEW JERSEY'S REGIONALIZED OCEAN OUTFALLS AND THE AVAILABILITY OF USEFUL DATA. INFORMATION CONTAINED HEREIN INDICATES A PREDOMINANT NORTH-SOUTH FLOW ALONG THE NEW JERSEY COAST EXCEPT AT POINTS NEAR TIDAL INLETS WHERE A ROTARY FLOW CAN BE EXPECTED. THE PHOTOMAP ON WHICH THIS INFORMATION IS PLOTTED WAS PREPARED FROM BULK PROCESSED MULTISPECTRAL SCANNER (MSS) IMAGERY ACQUIRED BY THE NASA EARTH RESOURCES TECHNOLOGY SATELLITE (ERTS-1). THE IMAGE, A NEGATIVE OF BAND 7, WAS ACQUIRED IN THE NEAR INFRARED PORTION (800 - 1100 NANOMETERS) OF THE SPECTRUM.

LEGEND

- ◉ PROPOSED REGIONAL TREATMENT FACILITY
- • SEWAGE PLANTS PRESENTLY DISCHARGING INTO ATLANTIC OCEAN
- . OBSERVED OUTFALL LOCATIONS
- ▪ DYE SOURCE LOCATIONS



SCALE

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FIGURE 29

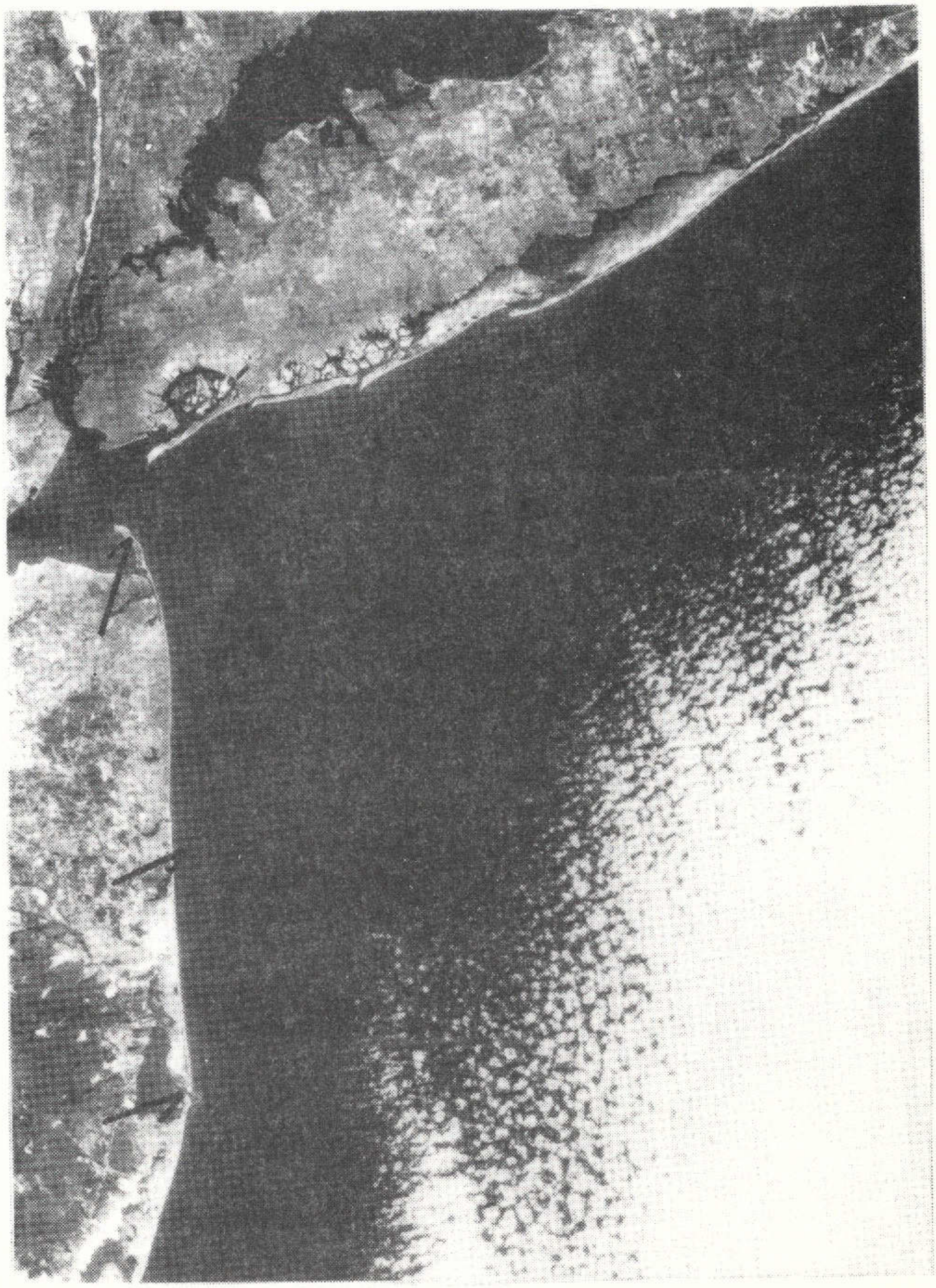


FIGURE 30. WATER MASS BOUNDARY FEATURES SUCH AS THESE IMAGED ON ERTS-1, ARE USEFUL IN DEFINING CIRCULATION CONDITIONS IN THE NEARSHORE ZONE. 12 FEBRUARY 1973 ERTS MSS BAND 5.

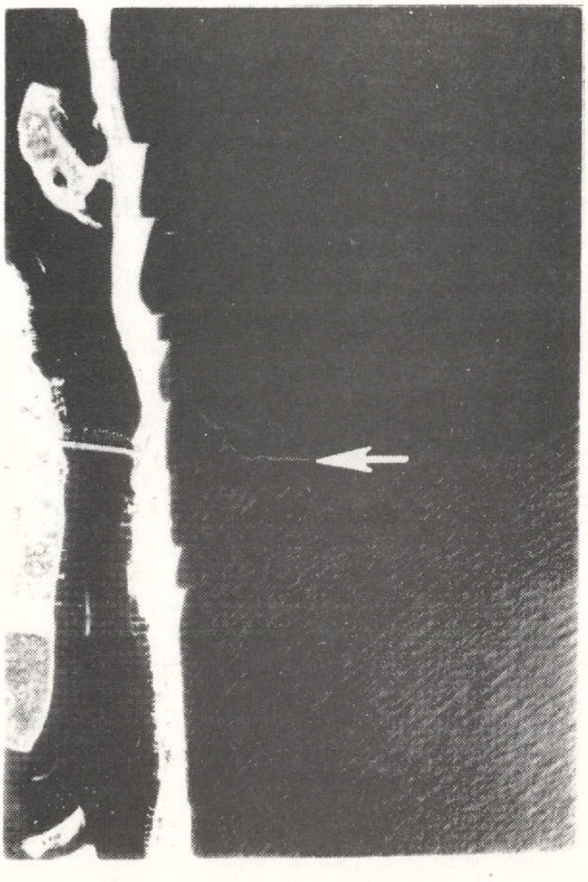
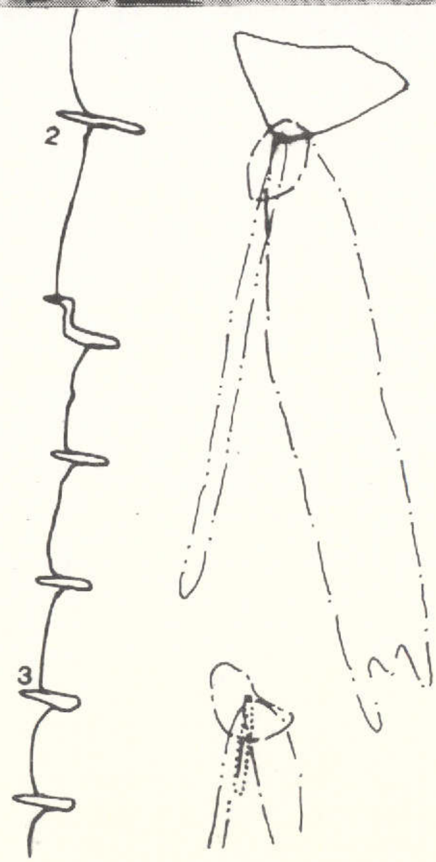


FIGURE 31. ANCHORED DYE SOURCES IN COASTAL WATERS HAVE BEEN USED TO BETTER UNDERSTAND TIDAL CIRCULATION AND ITS EFFECT ON SEWAGE EFFLUENT MOVEMENT.

Information products were prepared so that they were useful and self explanatory to the resource manager. The Outfall Planning Map (Figure 29) was developed to fulfill these needs. It was prepared from analysis of seventeen (17) orbits of ERTS-1, nineteen years of supplementary aircraft photography, and historical ground records. The technique utilized for delineating the circulation information presented on the map was to scan each ERTS-1 frame (all MSS bands) for any reflective differences associated with various water mass boundaries in the nearshore waters. All MSS bands were used so as to verify that a given phenomena was in fact in the water and not atmospheric in origin. If the feature was imaged in all MSS bands, it was not a water feature as all energy in MSS band 7 and most all energy in MSS band 6 is absorbed within the first few millimeters of the water's surface. MSS bands 4 and 5 were the most useful for delineating water mass features and identifying circulation characteristics. As features were observed on the ERTS imagery their shape, symmetry, and apparent movement were compared with the local climatological information and tidal conditions. In this way, current directions could be interpreted for selected areas along the coast. Field verification was performed using boats at various stages in the analysis.

Aircraft photography was analyzed using a similar technique to that of ERTS analysis; however, most of the data obtained from the aircraft photography was derived from the direction of drift of imaged outfall plumes (Figure 32).



Repetitive aerial coverage of ocean outfalls, such as the one above, yields information on surface flow of the waste field under differing environmental conditions. These analyses have contributed to the more environmentally sound placement of ocean outfall locations.

ORIGINAL PAGE IS OF POOR QUALITY

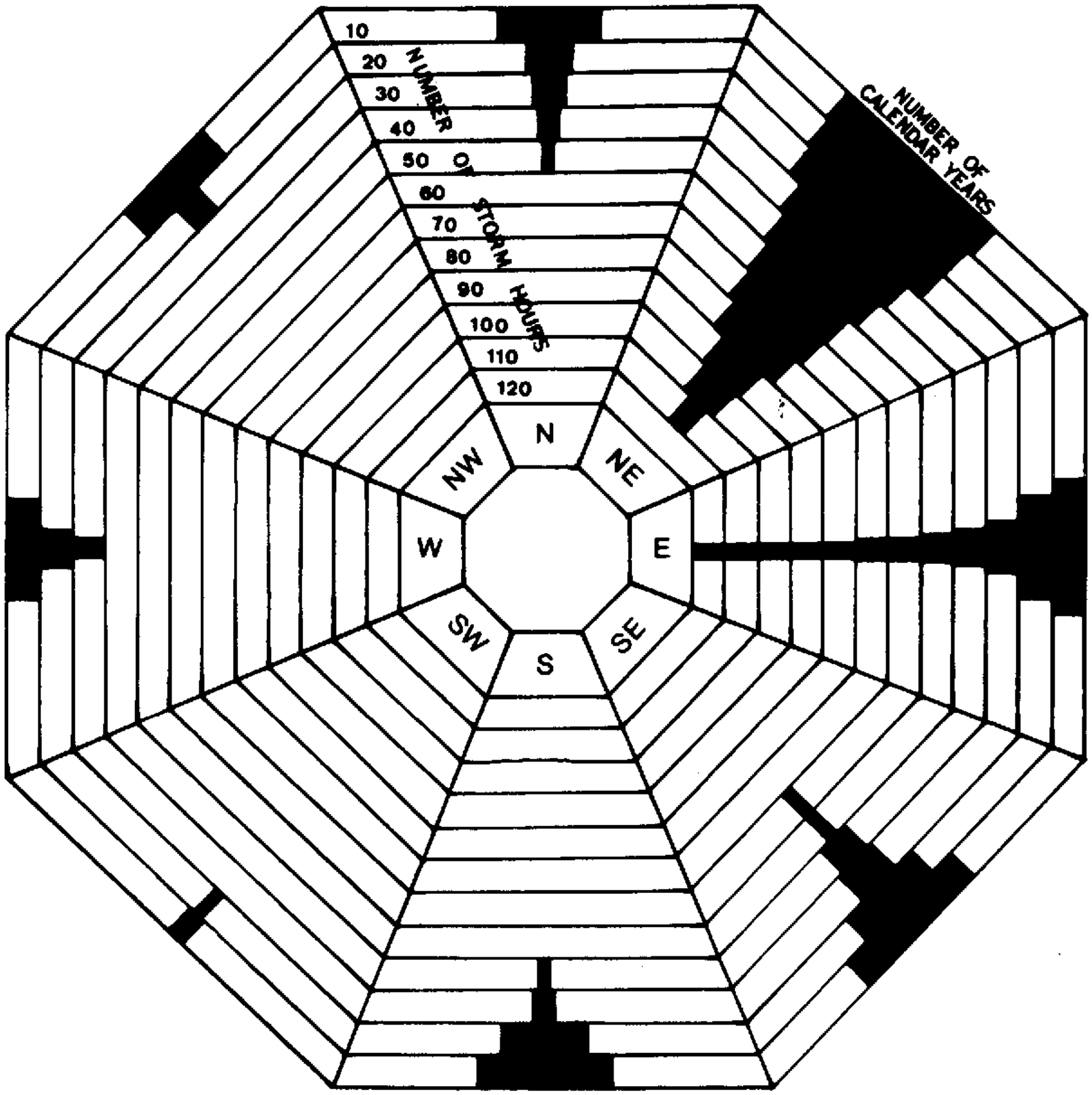
OCEAN OUTFALL PLUMES

FIGURE 32

After analysis of all pertinent ERTS frames and the aircraft photography, the total number of observations and their respective directions were compiled and the data were plotted on rosette histograms as seen on the Outfall Planning Map. Each histogram represents the percent of time surface currents have been observed to flow in the directions indicated within an area just outside the littoral zone extending to one (1) mile offshore. The data presented on the map indicates that a predominant north-south flow exists along the New Jersey coast except at points near tidal inlets where a rotary tidal flow can be expected.

These data sets may be somewhat biased by the fact that information was only obtainable on clear days. Surface current information on overcast days could be entirely different because of associated storm systems, etc. It was, therefore, necessary to attempt to establish a relationship between climatological conditions and the observed surface currents so one could then extrapolate the climatological conditions on overcast days to a surface current condition.

To make these comparisons, a compilation of storm wind data (Figure 33) and normal wind data (Figure 34) was made in order to relate these data to the wind driven current overlay (Figure 11) prepared in an early stage of the investigation. This comparison was made defining the correlation between surface wind direction and speeds to surface water current conditions. A statistical analysis of the observed surface currents related to the recorded wind direction and speed



SCALE FOR NO OF CALENDAR YEARS

0 5 10 15

FIGURE 33. STORM WIND DATA TAKEN AT ATLANTIC CITY, NEW JERSEY DURING THE PERIOD 1938-1958. THE HISTOGRAM ILLUSTRATES THE PREDOMINENT STORM WIND DIRECTIONS AND DURATIONS.

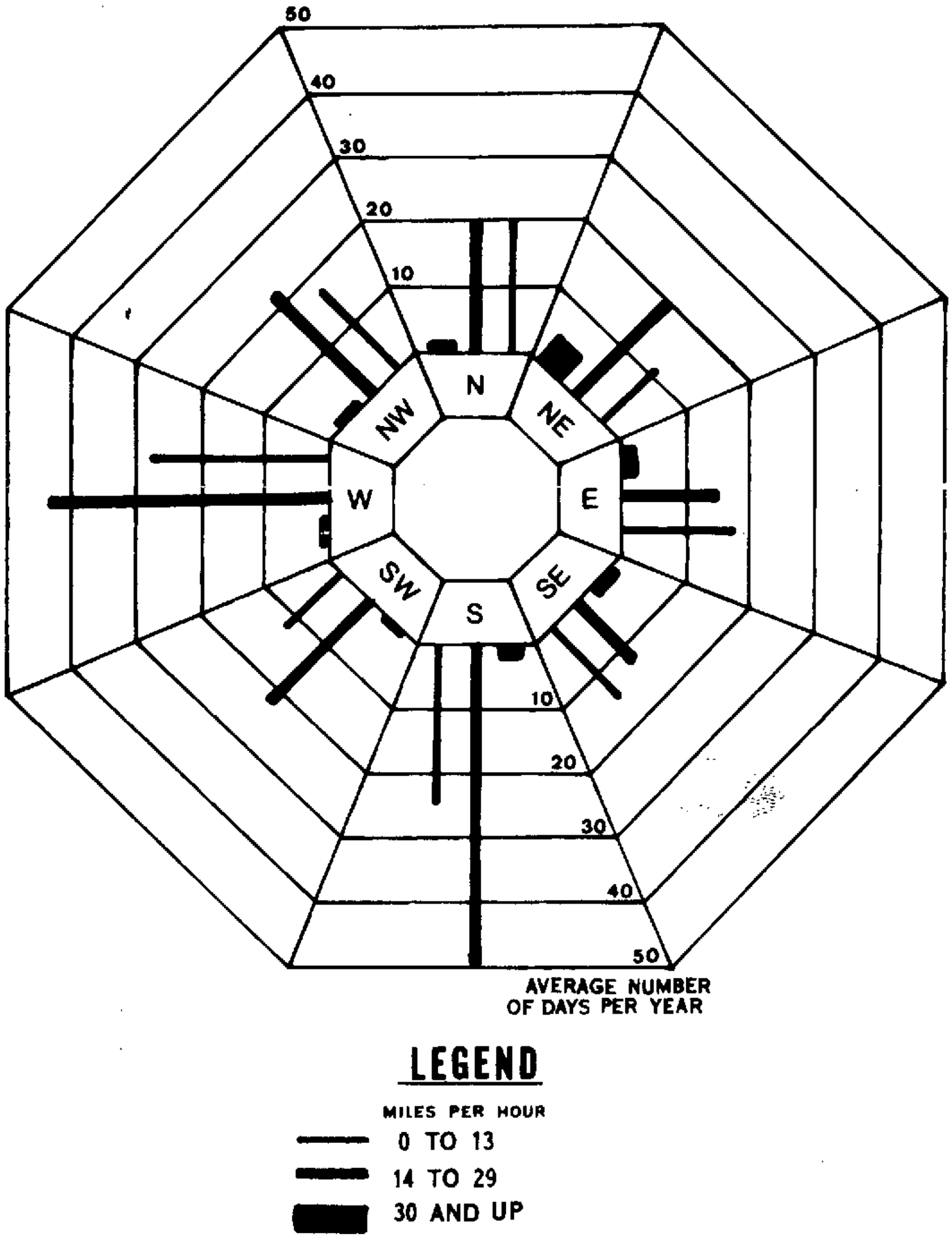


FIGURE 34. AVERAGE WIND SPEEDS AND DIRECTIONS FROM 1936 -1952 AT ATLANTIC CITY, NEW JERSEY. HISTOGRAM ILLUSTRATES THE AVERAGE NUMBER OF DAYS WINDS BLEW FROM VARIOUS COMPASS DIRECTIONS AND A BREAK-DOWN OF WIND SPEEDS.

data, and the threshold wind velocities needed to produce a significant surface current, shows that approximately 60% of the time the surface current is onshore in areas not affected by tidal action associated with a tidal inlet. In other words, the movement of surface waters in the nearshore zone is toward the shore approximately 60% of the time. This is much more often than had been thought by NJDEP officials.

The monitoring of existing ocean outfalls (Figure 35) thus became an important task within the investigation. New Jersey has numerous ocean outfalls of various capacities and ERTS-1 and aircraft image analysis has shown some patterns of surface plume movement at selected outfalls that cover all possible points of the compass. The predominant factors in the movement of surface outfall plumes were found to be the tides and winds; and since the prevailing winds that occur in coastal areas are onshore, the need to understand the movement of surface waters becomes most important. Figure 36 represents the maximum displacements of an ocean outfall surface plume for four different directions of flow. Maximum observed surface plume length has been measured at 1500 meters whereas many of New Jersey's outfalls are only 350 meters offshore. When the prevailing surface currents are onshore, there is a large-scale inundation of the beach by the sewage effluent plume at and around these outfall locations. This condition is clearly represented on Figure 35.

The investigators worked closely with the local sewerage authorities and the design engineers to develop the necessary marine current data needed to plan sewage disposal systems

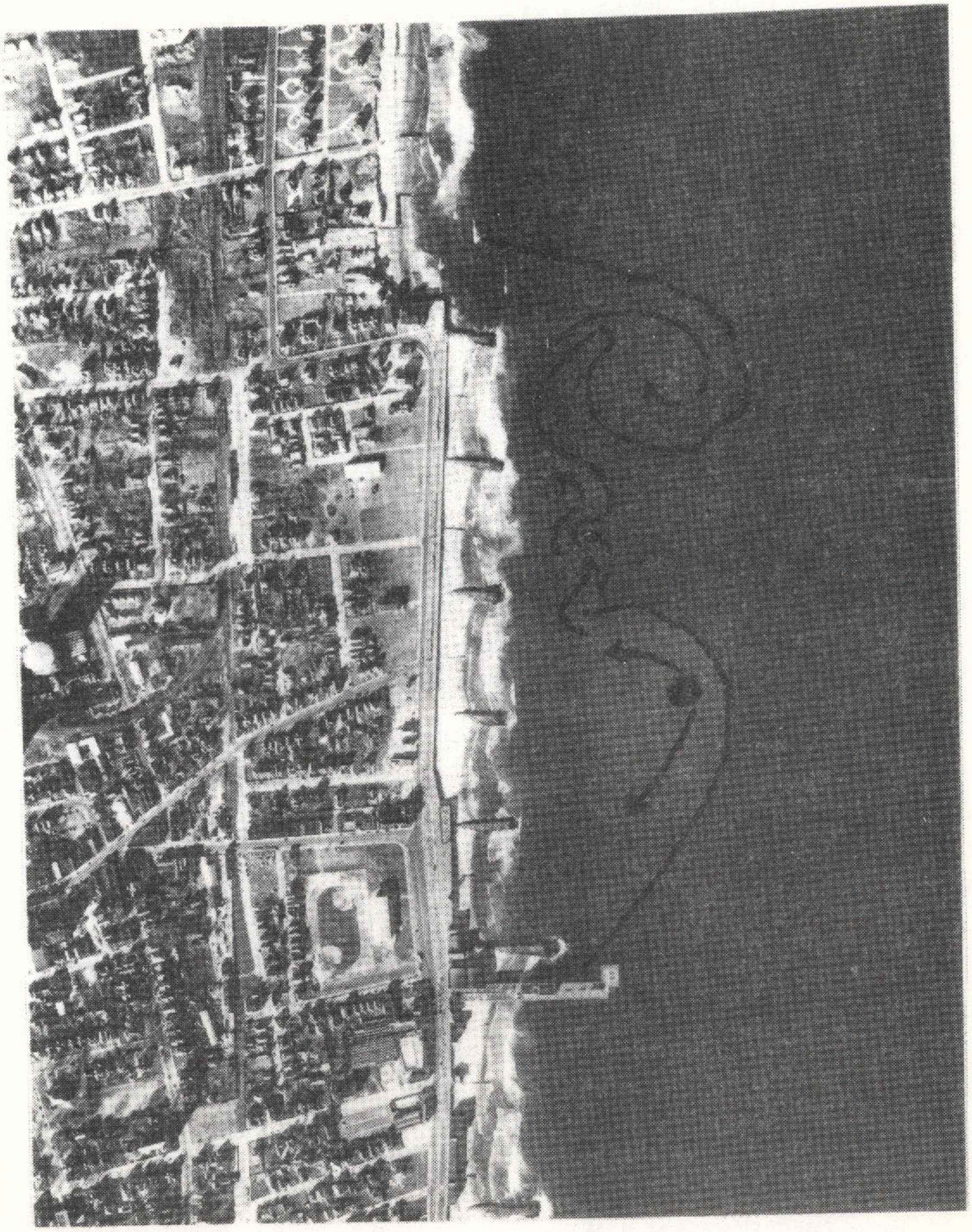


FIGURE 35. SURFACE PLUME FROM AN OCEAN OUTFALL WHICH EXTENDS APPROXIMATELY 1000' OFFSHORE. AS CAN BE SEEN FROM THIS PHOTOGRAPH THE SEWAGE EFFLUENT UPON RISING TO THE SURFACE MOVES DIRECTLY ONSHORE INUNDATING THE NEARBY BATHING BEACHES.

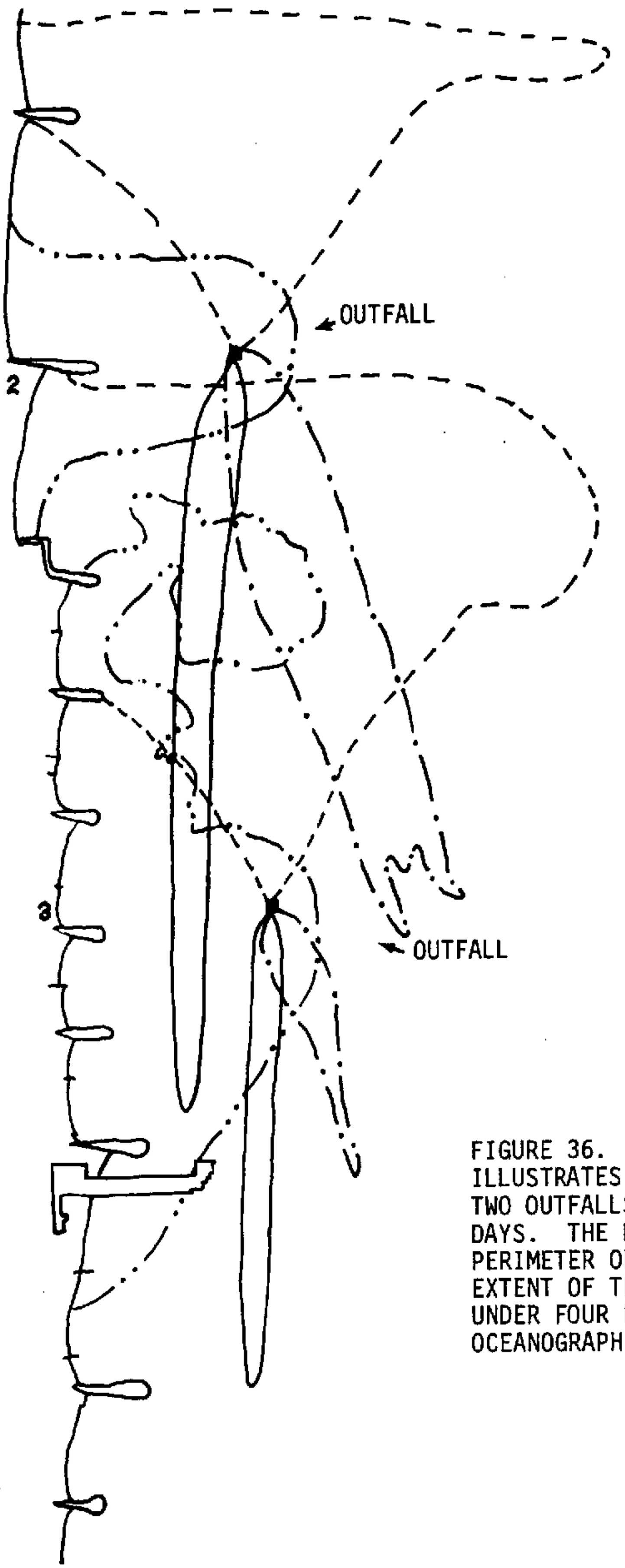


FIGURE 36. THIS LINE DRAWING ILLUSTRATES THE CONDITIONS AT TWO OUTFALLS ON TWO SEPARATE DAYS. THE LINES REPRESENT THE PERIMETER OR MAXIMUM SURFACE EXTENT OF THE TWO OUTFALLS UNDER FOUR DIFFERENT CLIMATIC/ OCEANOGRAPHIC CONDITIONS.

that are in balance with the surrounding environment. Various meetings took place during this investigation and a working relationship was established. Local sewerage authorities and the design engineers are now looking into the effects of circulation on waste water disposal and are eager to participate in further evaluations of their systems and in the analysis of remote sensing data.

4.2.4 Shore Protection

The feasibility of using ERTS imagery to provide the information needed by NJDEP for shore protection planning (including allocation of funds) was investigated. ERTS images from different dates and spectral bands were superimposed on a color additive viewer. The color additive process highlighted changes in the position of the shoreline. When a change in the position of the shoreline occurred it appeared as a one color "fringe" along the coast. This fringe was seen only once during the investigation. The observed change was later attributed to a difference in tidal stage in a low lying wetland area. It was determined that even though it is possible to detect large shoreline positional changes, the spatial resolution of ERTS must be improved before shoreline changes, of a magnetude important to shoreline management, can be detected and monitored.

Because ERTS data could not provide the shore protection management information required by NJDEP this investigation was conducted using low altitude aerial photography and was a demonstration of a method of analysis that can be applied to coastal zone management problems.

As the understanding of the natural and economic factors that control the evolution of the coast increases, new shore management policy directions will emerge. The central policy question appears to be: should the state continue to fund shore protection efforts throughout the state? This issue has far-ranging economic implications that extend beyond the understanding of the natural phenomena of the shore and near shore zones. The objective of this investigation was however to understand and document the natural phenomena; this understanding can then serve as a basis for developing shore protection policies. The products produced would eventually be used in making management decisions within the framework of the emerging NJDEP shore management policies.

A case study was designed as a demonstration of a first step data analysis that could answer such NJDEP questions as:

- What were the present erosion/accretion rates at any point along the coast and what were the historical trends of shoreline positional change at that point?
- What areas of the coast were now critically eroding?
- Disregarding the absolute value of erosion, how severe was the erosion at any given point along the coast?
- Where were shore protection projects needed?

The detail of each investigation would, of course, dictate the detail of the answer.

The question of where and how much money should be spent on shore protection projects can be answered by evaluating the cost effectiveness of past shore protection expenditures. In addition to understanding the natural beach processes, consideration of the economic impact of a management decision dealing with shore protection expenditures is necessary.

Property values, erosion rates and proposed shore protection expenditures will be an integral part of a NJDEP management decision model.

This proposed decision model will take into account the identification of past erosion trends, estimates of future erosional trends, and cost effectiveness of maintenance and construction of shore protection structures. The cost effectiveness evaluation will consider <u>three</u> basic variables and classify them as either HIGH (H) or LOW (L):

(1) Cost of construction or maintenance;

(2) Rate or severity of erosion in the area;

(3) Value of property protected.

Table 4 illustrates the possible combinations of the three variables that would yield a decision.

TABLE 4

Example of a Possible Shore Protection Decision Model

Combination of Variables	Unacceptable				Acceptable			
Shore Protection Expenditure	H	H	H	L	H	L	L	L
Recession Rate	H	L	L	H	H	L	L	H
Property Value	L	H	L	H	H	L	H	L

Consider: An unacceptable combination of a HIGH shore protection expenditure in an area with a LOW recession rate and LOW property value. In this case, money is being wasted because the erosion rate is LOW, and this land is not valuable enough, economically, to justify a large expenditure for protection. Conversely, for an acceptable combination a HIGH but acceptable expenditure is being made in an area of HIGH property value and HIGH rates of erosion.

Before a management decision model could be constructed, certain data were needed. The primary data source for this investigation was low altitude aerial photography taken during the time period 1954-1971. Attention was focused on two test sections with contrasting beach environments. One test section is characterized by a nearly continuous complex of seawalls, bulkheads, groins and jetties with dense residential and commercial development throughout the section. Geographically, this northern test section extends approximately 20 miles from Highlands Beach to Manasquan Inlet. There were 53 stations at which measurements were made on aerial photographs. A second test section was characterized by a primary and secondary row of artificially stabilized dunes. The dunes were densely vegetated except at various locations where wave erosion had removed part of the dune and the plant community had not reëstablished itself. This section is unique, for it is the only undeveloped ocean coastland in New Jersey. The area extends approximately 9 miles from Seaside Park to Barnegat Inlet, and includes the entire Island Beach State Park. In this test section there were 31 stations at which measurements were made on aerial photographs.

The information measured and calculated from the total of 84 stations in two test sections included:

- Rates of erosion and accretion for the duneline and the high water line at each station
- Mean rates of erosion and accretion
- Beach width at each station
- Point of maximum sea encroachment at each station
- Erosion and accretion indices (indicating the magnitude of the positional change of the high water line or dune line in relation to the beach width).

The methods of computing these values and their analysis is included in Appendix B (Figures 39-47 and 51-54 also appear in Appendix B).

Positions of the high water line, dune line, and bulkhead line were measured relative to fixed reference points chosen on aerial photographs taken by NJDEP in the years 1954, 1957, 1960, 1961, 1962, 1963, 1966, 1969, and 1971. The photographs chosen were taken approximately every third year beginning in 1954 with the exception of the interval 1969-1971 and the 'close-look' analysis of coastal conditions immediately preceding and following the Great March storm of 1962 (1960-1961, 1961-1962, 1962-1963).

A discussion of the dynamic processes that shape the New Jersey coast can be found in Appendix C. This discussion is presented so that the results of this study may be fully appreciated. The beach is the single most dynamic geomorphic feature in the coastal zone. Changes are continual; they may be so small as to be imperceptible, or they may be catastrophically large. These changes may be erosion or accretion of the beach and dunes, but in either case, the energy sources are incoming waves and winds.

The typical groin system Figure 37 along the New Jersey coast extends seaward of the breaker zone, effectively confining littoral transport mechanisms between groins, allowing little or no littoral transport of material past each groin. The actual effect of these systems on the environment was of concern in this investigation. Rates of erosion and accretion were calculated in order to classify shore protection structures environmentally sound or unsound and to recommend management alternatives.

The calculated rates of erosion and accretion for both test sections are presented in graphic and tabular form (Appendix D). The measurement stations are numbered from 1 to 53 (right to left, Figure 38) for the northern test section and 54 to 84 for the southern test section. Breaks in the line graph indicate missing data, and in the tables missing

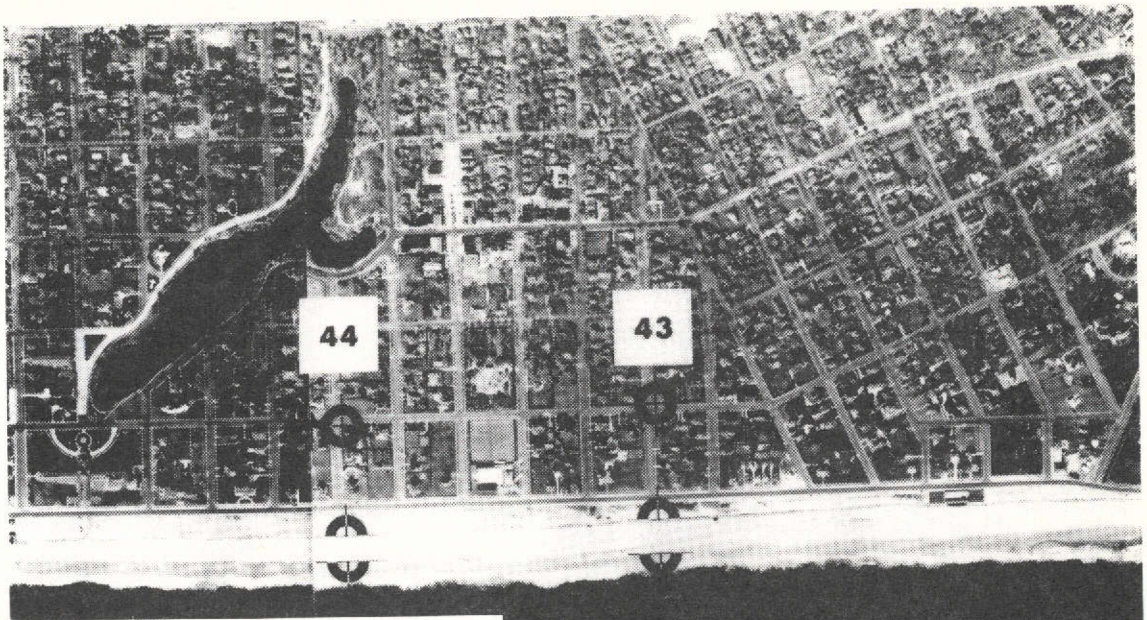
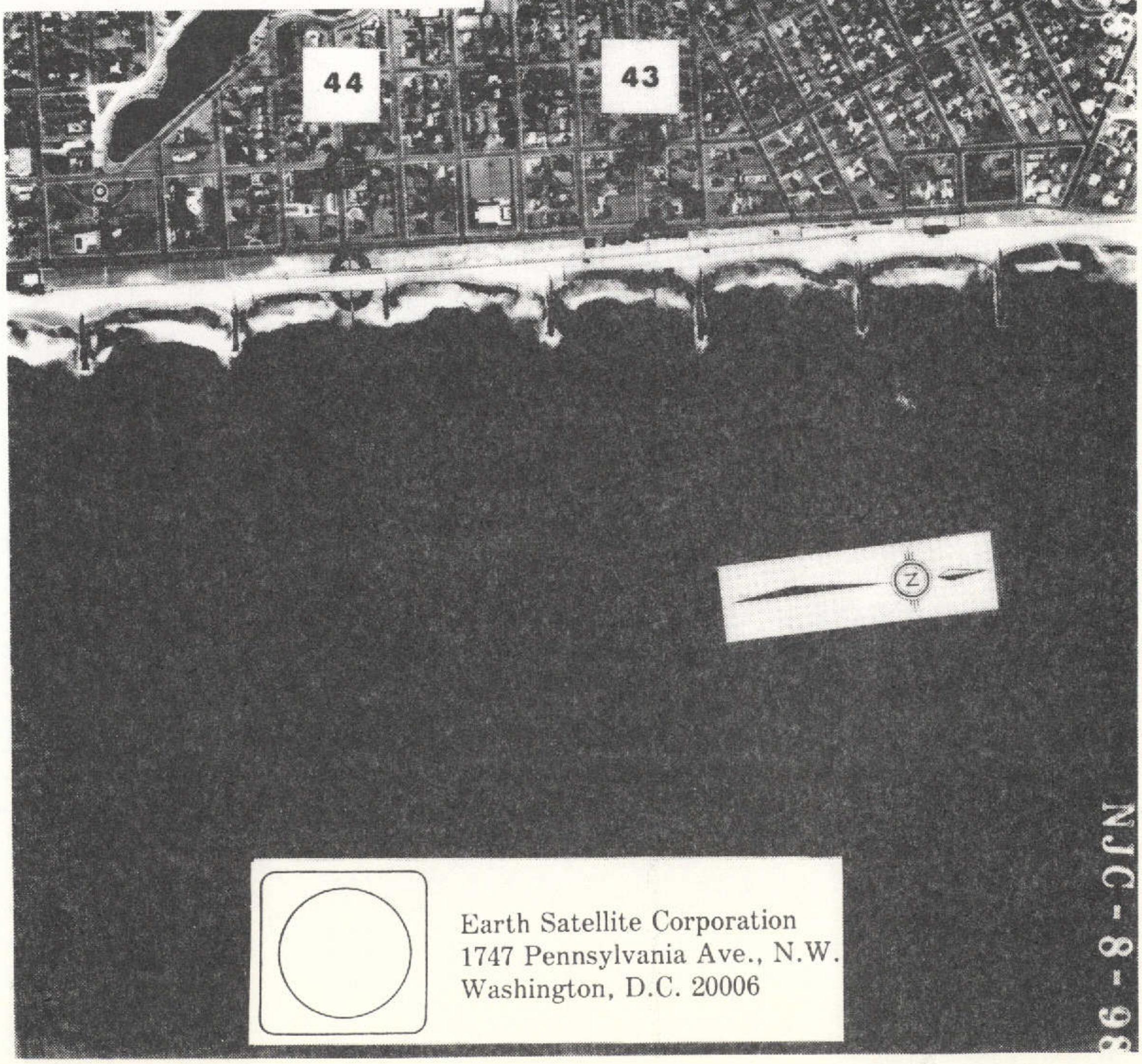


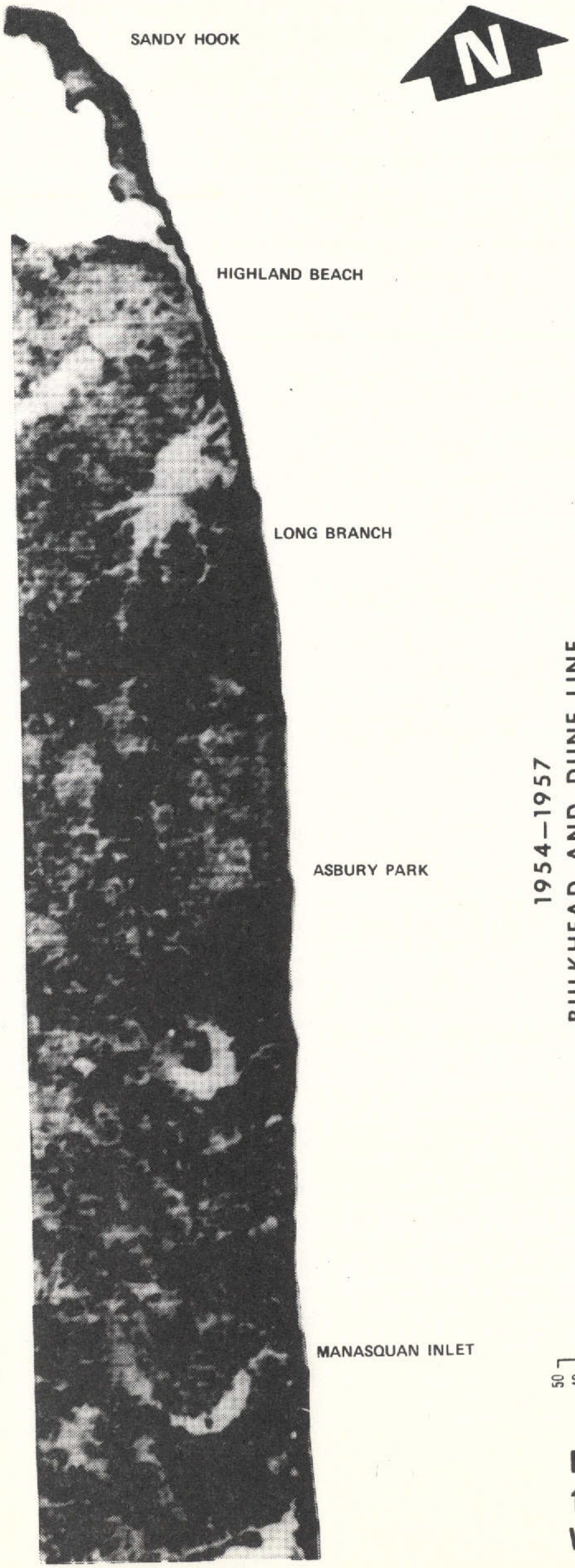
FIGURE 37

This is the beach at Spring Lake, New Jersey before and after the construction of a groin system.

Dates: Upper photo, 4/30/54
Lower photo, 2/28/71

Scale in feet 0 800 1600





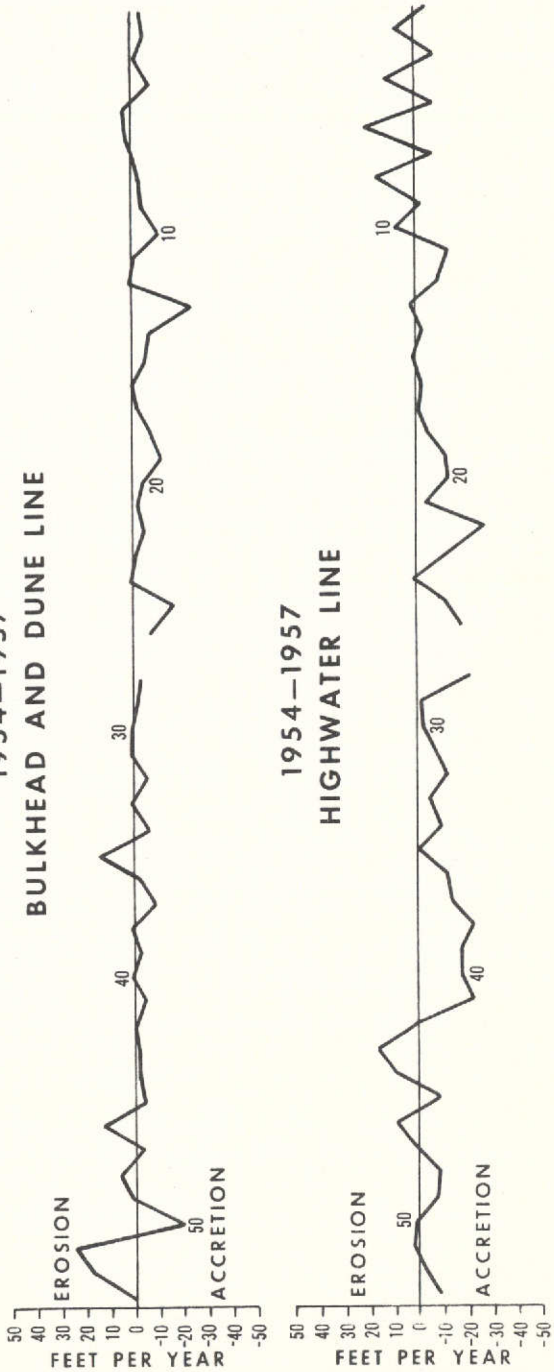


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FIGURE 38

RATE OF CHANGE GRAPH, NORTHERN TEST SECTION 1954-1957 data is also indicated.[9/] The graphs are positioned along side of an ERTS Basemap so that each station corresponds to its actual geographic location.

From the rate of change graphs a rapid qualitative evaluation can be made of the erosion and accretion events that occurred within a given geographic area during a specified time interval. Specific points along the coast that have experienced high rates of erosion or accretion are readily identified; and those areas that experienced a net change of zero are also easily identified. A qualitative estimate of the overall regional changes can be made rapidly by observing what percent of the graph is above or below the zero change line.

The mean rates of erosion and accretion illustrate the relative instability of the high water line in the northern test section during the intervals 1954-57, 1957-60, 1960-63. (Figures 48-49) The northern high water line erosion and accretion rates are higher than the high water line rates in the south, indicating more active transport of sand in the northern section. Part of the instability is the result of beach fill producing high apparent accretion rates in certain places and the construction of groins which impound littoral drift and starve certain areas of the coast; this could account for some high erosion rates. In 1963-66 there appears to be a reversal in the high water line trend. The southern high

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[9/] Missing data was due to the unavailability of aerial photographs for a given situation.

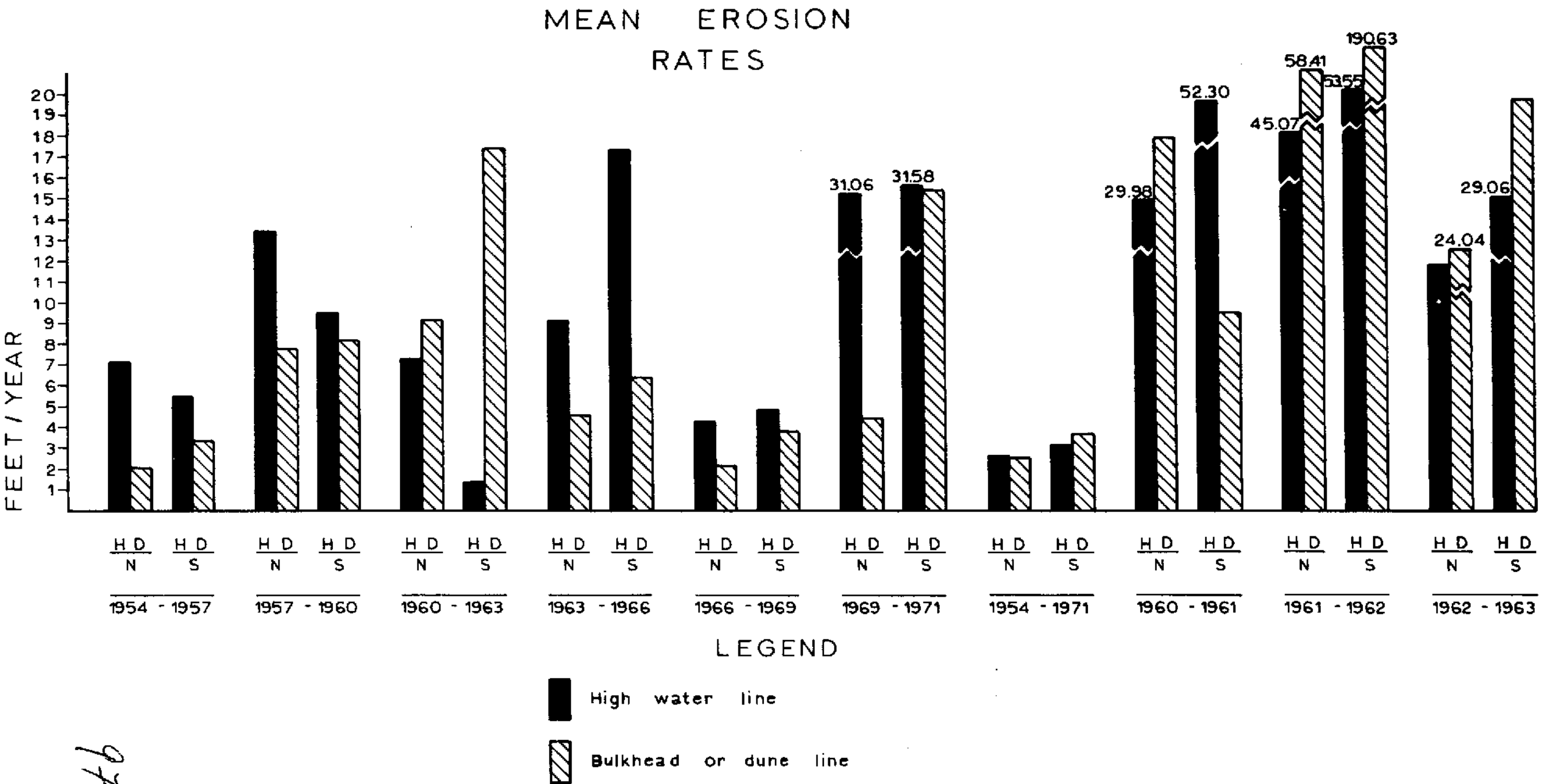

MEAN EROSION RATES
FEET / YEAR
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
31.06
31.58
29.98
52.30
45.07
58.41
53.55
190.63
24.04
29.06
H D
N
S
1954 - 1957
1957 - 1960
1960 - 1963
1963 - 1966
1966 - 1969
1969 - 1971
1954 - 1971
1960 - 1961
1961 - 1962
1962 - 1963
LEGEND
High water line
Bulkhead or dune line

FIGURE 48

97

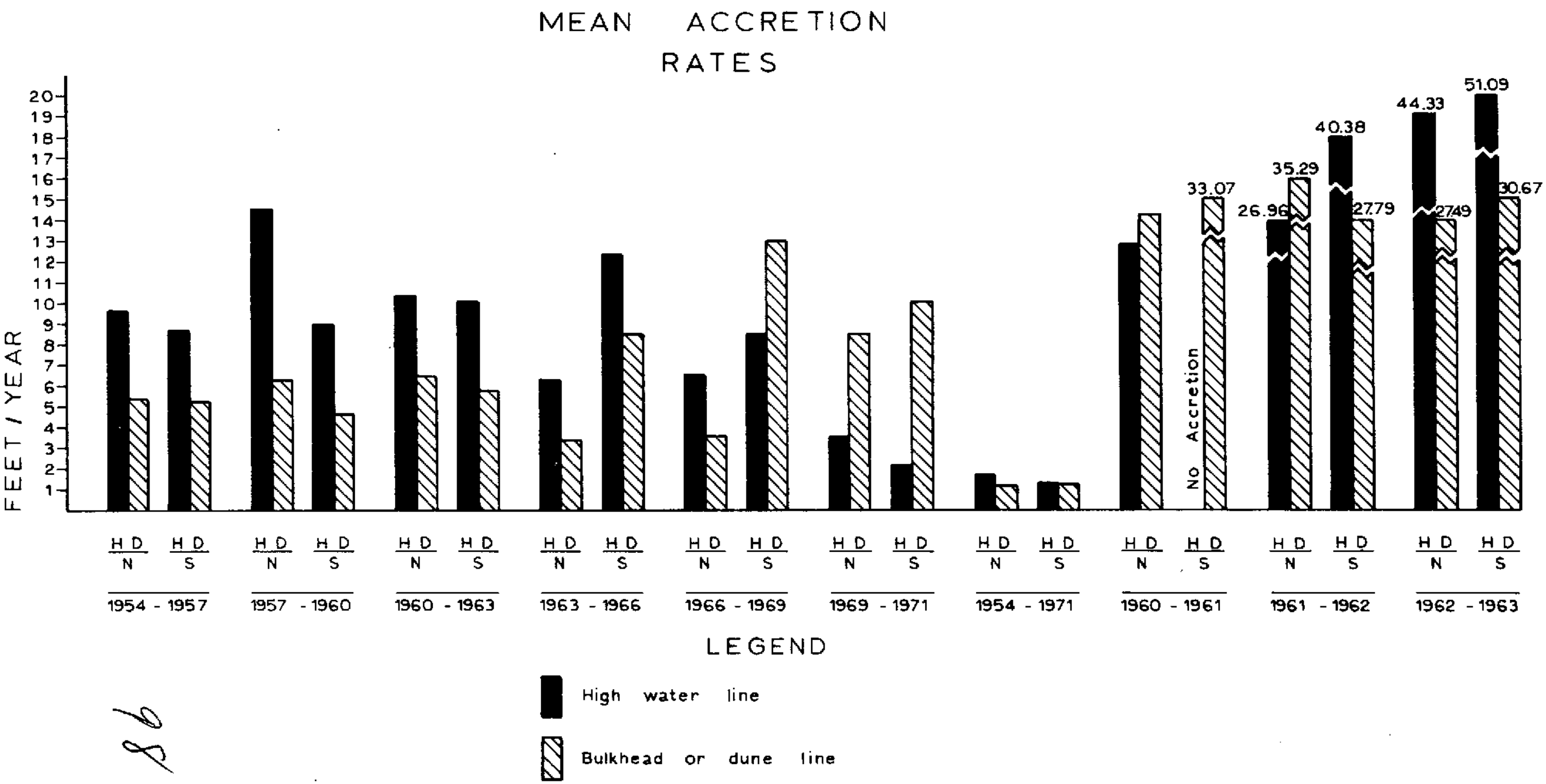

MEAN ACCRETION RATES
FEET / YEAR
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
33.07
35.29
26.96
40.38
27.79
44.33
27.49
51.09
30.67
No Accretion
H D N
H D S
1954 - 1957
1957 - 1960
1960 - 1963
1963 - 1966
1966 - 1969
1969 - 1971
1954 - 1971
1960 - 1961
1961 - 1962
1962 - 1963
LEGEND
High water line
Bulkhead or dune line

FIGURE 49

98

water line erosion and accretion rates are higher than the northern rates. This is the first full time interval after the 1962 storm. The high rates are attributable to the natural transport and redistribution of sediment disrupted by the storm. During the storm the high water line accreted a certain distance beyond which the position of the high water line would not be maintained during conditions of lower wave energy. The overall result within the southern test section was for erosion to occur at stations with a foreshore sand surplus and accretion to occur at stations with a foreshore sand deficit. This explains the inconsistancy of the high mean rates of erosion and accretion within the same test section during the 1962-63 time interval (Figures 48, 49).

The 1966-69 time interval was one of low erosion and comparatively high accretion in both sections. However, the rates of accretion in both the high water line and dune line were higher in the undeveloped southern section due to the greater abundance of sand; this indicates the recovery potential of the undeveloped beach. Appendix E contains the mean and standard deviations of all rates within each test section for all time intervals.

Beach width and the change in beach width are as important as the rate of shoreline positional change. The beach width is of course directly related to the positional change of the high water line and the dune line. Using Figure 50, it is

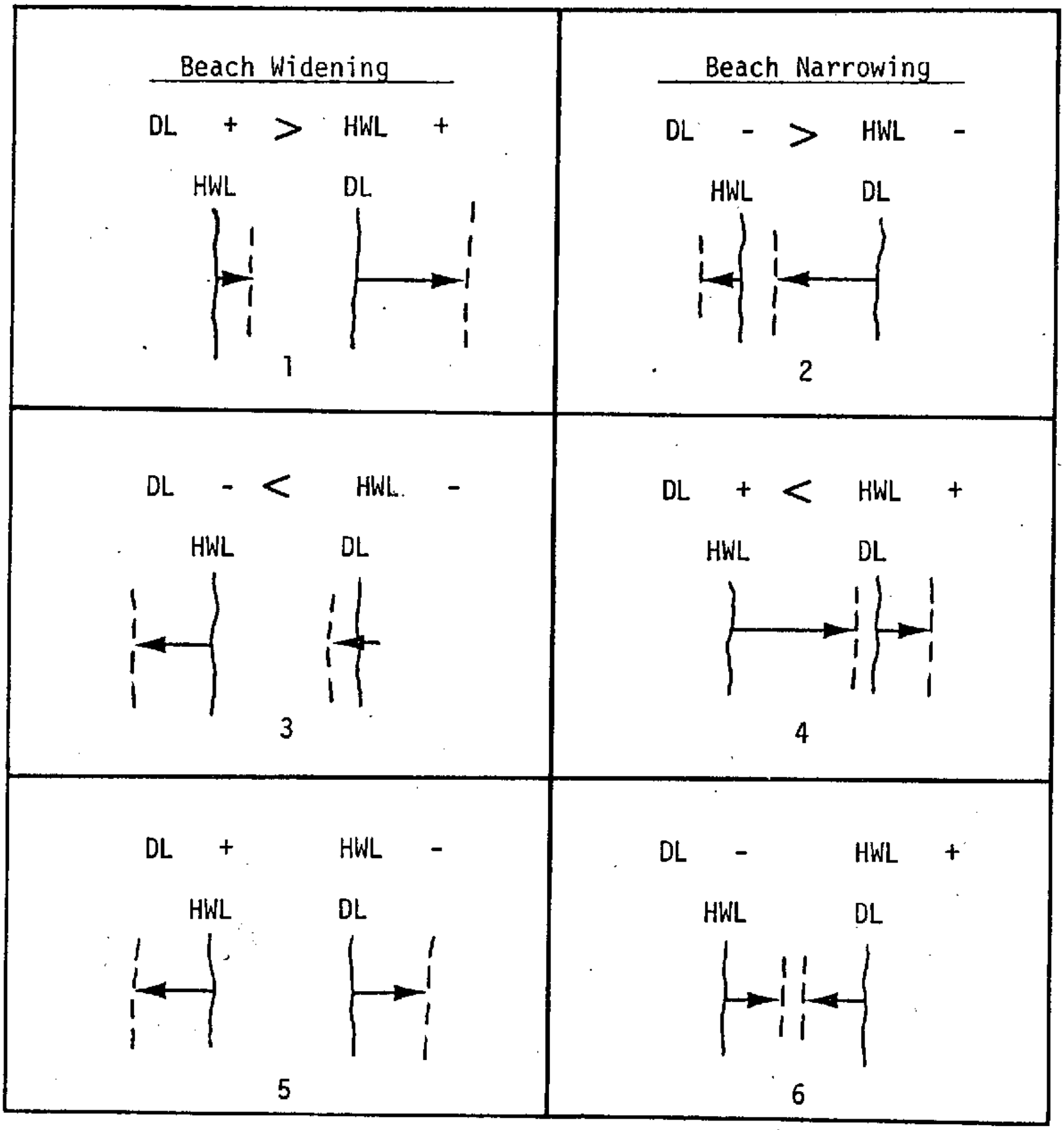
CHANGES IN BEACH WIDTH

+ HWL Rate of High Water Line Erosion

+ DL Rate of Dune Line Erosion

- HWL Rate of High Water Line Accretion

- DL Rate of Dune Line Accretion



100

FIGURE 50

possible to determine whether the beach is becoming wider or narrower from the rate-of-change graphs. Six possible conditions of beach width changes are illustrated. If, for example, the dune line erodes at a rate that is greater than the high water line erosion rate, the beach will become wider (Figure 50 [1]), or if the dune line erodes and the high water line accretes, regardless of the rate, the beach will become wider (Figure 50 [5]).

The beach in the southern section (Island Beach State Park) is generally wider than the beach in the northern test section (Highlands Beach to Manasquan Inlet). The mean minimum beach width in the southern section is 136 feet (Table 5) while the mean minimum beach width in the northern section is only 74 feet (Table 6). In fact, 40% of the 53 stations in the north had a minimum beach width of less than 50 feet. 20% of the 53 stations did not have a subaerial beach at all. The standard deviation of the northern section mean minimum beach width (S.D. 63) is slightly less than three times as great as the standard deviation of the southern section mean minimum beach width (S.D. 24). This is strong quantitative evidence for the disproportionate distribution of the sand supply on the beaches in the highly-developed northern test section. These should be alarming statistics for an area that considers its beaches to be a significant recreational asset.

TABLE 5

MINIMUM AND MAXIMUM BEACH WIDTHS

ISLAND BEACH STATE PARK
(SOUTHERN SECTION)

MINIMUM AND MAXIMUM BEACH WIDTHS

ISLAND BEACH STATE PARK

STATION	MINIMUM	MAXIMUM	STATION	MINIMUM	MAXIMUM
54	152.3	211.2	79	134.0	369.2
55	82.1	232.0	80	133.7	272.3
56	148.1	286.8	81	135.7	265.8
57	170.5	260.0	82	116.0	275.9
58	180.4	274.6	83	111.1	312.7
59	142.8	263.4	84	106.9	337.0
60	147.3	327.0			
61	143.8	246.8			
62	139.9	297.1			
63	186.4	277.2			
64	118.7	247.1			
65	117.4	285.1			
66	152.6	360.3			
67	139.5	247.8			
68	186.8	270.6			
69	149.2	242.2			
70	126.8	245.0			
71	129.1	279.6			
72	160.3	302.8			
73	127.4	371.2			
74	115.2	236.2			
75	124.8	296.5			
76	106.0	226.1			
77	121.2	220.9			
78	138.9	278.7			

Beach widths expressed in feet

Mean Minimum Beach Width 136.983

Standard Deviation 24.016

Mean Maximum Beach Width 278.086

Standard Deviation 41.876

TABLE 6

MINIMUM AND MAXIMUM BEACH WIDTH

HIGHLANDS BEACH TO MANASQUAN INLET
(NORTHERN SECTION)

MINIMUM AND MAXIMUM BEACH WIDTHS

HIGHLANDS BEACH TO MANASQUAN INLET

STATION	MINIMUM	MAXIMUM	STATION	MINIMUM	MAXIMUM
1	54.0	140.8	28	42.0	171.2
2	0.0	73.4	29	78.4	166.4
3	0.0	50.1	30	126.9	228.5
4	49.3	303.5	31	153.5	197.1
5	0.0	126.6	32	94.3	172.6
6	7.1	171.8	33	75.5	164.8
7	162.4	327.8	34	59.9	158.3
8	21.5	221.5	35	31.4	203.1
9	0.0	61.3	36	74.1	260.1
10	0.0	88.0	37	344.8	511.7
11	0.0	80.7	38	183.1	263.6
12	0.0	179.8	39	94.7	180.9
13	127.0	344.4	40	190.3	265.7
14	48.0	164.0	41	136.4	210.5
15	59.8	238.3	42	108.1	178.1
16	43.3	112.5	43	103.9	204.8
17	0.0	74.5	44	85.1	191.4
18	32.4	110.7	45	99.4	158.6
19	22.1	99.3	46	88.6	172.2
20	88.0	169.6	47	69.0	155.2
21	95.4	177.3	48	67.4	177.2
22	49.6	145.4	49	84.9	168.4
23	49.3	127.5	50	99.5	231.1
24	0.0	99.7	51	93.2	233.2
25	135.6	320.2	52	101.9	230.0
26	101.6	163.8	53	130.3	220.7
27	0.0	12.3			

Beach widths are expressed in feet

Mean Minimum Beach Width 74.808

Standard Deviation 63.580

Mean Maximum Beach Width 182.315

Standard Deviation 84.061

The mean maximum beach width for the northern section is 182 feet and the standard deviation is 84, indicating that there is a wide range of beach widths. The mean maximum beach width in the southern section is 278 feet and the standard deviation is 41 indicating a more consistent maximum width. The high degree of beach width variability in the north by contrast with the south is evidence of a difference in magnitude of the processes of erosion and accretion along the coast of the northern section.[10/]

By computing erosion and accretion indices based on both rates of change and beach width, the quantitative significance of a beach change can be determined.

In the northern test section there is a wide range of sharply contrasting erosion indices; severe erosion occurs at certain points within the test section. However, at adjacent points severe erosion does not occur. One explanation is that, depending on the configuration of a groin system, there are areas of the beach where sediment is trapped within the groin field, thereby providing an ample supply of sand which acts an expendable buffer during storms and a supply which can be quickly replaced by waves after the storm. However, at the

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10/ Even though the two test sections are in proximity, have a similar orientation to ocean waves, and have a similar sediment source they are different in that the northern section is characterized by shore protection structures. These structures and beach nourishment projects were designed to, and do change the magnitude of beach processes by reducing incident wave energies. Some beachs therefore accrete while others erode.

next station downdrift there may be severe erosion because sand that normally would be transported to this station was impounded by the groin field immediately updrift.

The standard deviation from the mean erosion index in the northern test section is 8.32 while the standard deviation in the southern section is 4.5. This is a significant difference because in the absence of a groin system in the southern section, the erosion indices do not vary as much as they do in the north. The importance of this fact is that, in the northern section groins promote beach accretion, in one place while downdrift beaches are deprived of sediment for natural beach replenishment. When a groin has accumulated the largest fillet of sand that it can hold under given wave conditions, the rest of the littoral drift will bypass the groin. But since groins often extend seaward of the breaker zone the mechanism for transporting sediment along shore is now located at, or outside of the breaker zone, and not on the beach face (swash zone). The sediment in effect bypasses the beaches on the updrift side of the groin. Eventually the sand that was deflected seaward by the groin field will be transported inland to the beach face where it can nourish another portion of the coast perhaps by being trapped by another groin.

The graph of the mean accretion indices (Figure 52 Appendix B) for the northern section supports this "leap frog" theory of sediment transportation and deposition along the New Jersey shore. There is a high degree of variability in the accretion indices as indicated by the standard deviation, 23.0 (Appendix F). The accretion indices in the southern section show a low variability of sediment deposition (Figure 54 Appendix B). Accretion here is more consistent because there are no groins to encourage localized accretion or eorsion and there are no artificial beach filling operations to create high accretion rates.

The stations that have a mean index above the overall composite mean index and a frequency of occurrence greater than or equal to the mean frequency of occurrence are indicated by an asterisk in Appendix F. These stations experienced the greatest change in beach width at a high rate for the 17-year time interval. These changes may or may not be detrimental to the preservation of the beach or backshore areas. Closer examination should be made of the areas to determine if corrective action is necessary.

In the northern test section, 27% of all 53 stations had an erosion index with a high-frequency occurrence of above-average erosion. In the southern section, however, only 19% of the 31 stations fell into this category. Fifteen percent of the stations in the northern test section had an accretion rate above the mean accretion index with a high frequency of occurrence, while in the southern test section 22% of the 31 stations had a high frequency and an above-average accretion index. The conclusion is that erosion on the whole was more severe in the northern section and that accretion of greater significance occurred in the southern section. The wide beaches in the southern section have much lower change indices because they have been allowed to transgress and regress in response to a naturally dynamic environment rather than being confined by bulkheads and groins.

Results of this Shore Erosion case study indicate that in the northern test area (developed beach) erosion has occurred more often, is generally more severe, and the beach is slower to recover than in the southern test area (natural beach). From the study data it appears that it may be possible to define areas most likely to experience further erosion. This is not, strictly speaking, a statistical prediction but rather an assumption that a recognized trend will continue. The assumption of continued erosion in areas that have at one time experienced severe erosion is supported by the relationships between beach width and energy dispersion. As a beach erodes, wave energy is concentrated on a narrower beach surface. High wave energy per unit area subsequently results in accelerated erosion. These analyses have direct operational value to NJDEP with respect to geographical allocations of yearly funds for shore protection and may impact management decisions for future priorities as to the philosophy of shore protection. The calculation of these data is the first step in determining the effectiveness of various shore protection structures in preventing sand removal and encouraging sand accumulation.

Arriving at a shore protection management decision for NJDEP is a complicated process. To demonstrate the management applications of the data analysis techniques and products developed during this study, the following simplified outline of a shore protection decision process is referred to:

(1) Does a shore protection problem exist?

(2) Determine the nature of the problem.

(3) What are possible solutions to the problem?

(4) How much money is required?

(5) What is the justification for the expenditure and environmental alteration?

Rates and indices of erosion and accretion help to quantitatively identify and describe the severity of the problem. Erosion and accretion in the short term could often go unnoticed without the quantitative information on positional change. After a shore protection problem is identified, it must be further evaluated before a solution can be suggested. For example: The actual rate of high water line or dune line positional change is of obvious value when determining what corrective measures may be taken (i.e., should beach fill be used) and in the design of shore protection structures. This information would also be useful in planning back dune development: for example, should houses be built on pilings, does the rate of erosion pose a high risk to development? In these cases, less expensive, more expendable structures should be built.

When analyzing a shoreline problem using the proposed decision model, a high rate of erosion or accretion may be detected. The change index, however, could be quite low. This is an important fact to the planning of nearshore land use because even though erosion and accretion of the high water line exists alternately at high rates, the danger to development is relatively low if the beach is wide.

Various data summaries, mean erosion and accretion rates, beach width summaries and mean erosion/accretion indices are valuable in determining past long range trends in beach changes. With knowledge of these past trends of beach change together with other data such as sediment availability, coastal circulation, and storm frequency, etc., predictions of future beach changes could possibly be made.

The major problem associated with development along New Jersey's shoreline is, by definition, attempting to establish some degree of permanence within a dynamic system. "Shore protection," the practice of dune stabilization, artificial beach nourishment and the construction of groins, jetties, bulkheads, etc. is actually a misnomer. This practice is more aptly called "development protection." Nevertheless, shoreland development exists and is continuing. In dealing with the shoreland protection problem, there are three policy alternatives for NJDEP:

1. Fortify the coast with various structures, encourage deposition of sand by using groins and dune stabilization techniques, dredge and fill, or

2. Discontinue all practices of shore protection. Eventually remove all shore protection structures and allow wind and wave energy to proceed toward dynamic equilibrium with the existing coast, or

3. Do as little as possible to disrupt natural processes, leave those shore protection structures that can be determined to be of benefit to the system and remove those that create as much of a problem as they are intended to solve. If absolutely necessary, this policy may permit the construction of shore protection structures, or the stabilization of dunes. Unprotected areas will be left to reclamation by the sea.

In adopting any policy, NJDEP must make certain "trade-offs". It may cost a tremendous amount of money to protect the coast and maintain it in approximately its present state (1974). Costs in part can speak for the effectiveness of the measures taken low effectiveness, mean increased shore protection costs.

The "do nothing extreme" also would be a great expense, but it may be a short term expense: removal of all or most structures is a high one-time expense, reestablishment of near-natural conditions, including land acquisition and dune stabilization are other high one-time expenses. A severe drawback of this alternative is the extreme displacement of residential and commercial structures, and the attendant economic losses which must be borne by individuals and communities. Such a policy would incur strong political opposition. The bonus is to insure low-risk inland development which does not significantly alter natural process. From this development, easy access to the shore can be provided and even though the beach and dune system advances and retreats, there will always be a beach for public enjoyment.

Perhaps the best near-term compromise solution is the third shore-protection philosophy -- a combination of two extremes -- selective construction and artificial control of the coastal processes and managing selected areas of reestablished near-natural systems.

In the past the emphasis in shore protection in New Jersey was on the extreme of the first policy alternative, and since the idea of a compromise policy has been presented here, at least one suggested way of achieving that compromise should also be presented.

A relatively extensive and continuing data collection and investigation plan should be initiated. Work to be done would include:

- The design of a sampling plan and acquisition of aerial photographs of the entire coast, at least once per year -- preferably more often;
- Establish a computerized data base;
    - more stations for the entire New Jersey coast
    - store all rates, shoreline positional changes, beach widths
    - record groin field configurations

- describe each groin and characteristic sand fillet

- describe bulkheads, boardwalks, jetties, banks, dunes

- record wave data, storm frequencies, wind data

- record beach filling and dredging operations

With this data and its evaluation on hand

- past beach trends, present beach situation and estimated future beach configuration can be used to establish zones of high and low risk. Property within these zones would then be assigned a certain chance of survival; a risk factor.

- Assigned risk factors will be the basis for determining the amount of reconstruction money that the State or Federal government should pay owners in case of storm damage to shoreline property. The knowledge that government relief is not available to those who build in high-risk areas may be a deterrent to poorly planned uncontrolled development. It would also inhibit government underwriting of development in fragile areas of the coastal environment.

- In the same context as above, insurance companies would base premiums on shoreline risk zones further curtailing rampant development of the beach and land immediately adjacent to the beach.

The areas that are selected for protection, such as hospitals, historically significant areas, public utilities, etc. and immediately adjacent areas would be considered low-risk areas. Those areas selected for the reestablishment of the natural system would be classified as high-risk areas. The State might choose to acquire coastal land at market value and regulate further development.

5.0 CONCLUSIONS

The investigators, jointly, have developed remote sensing products (based on ERTS-1 and aircraft acquisition systems) which have helped the State of New Jersey solve practical coastal resource management problems. NJDEP officials now recognize the value of ERTS and aircraft remote sensing data in providing the kinds of information required for more effective coastal resource management.

Probably the most fruitful application of ERTS imagery, combined with aerial photomaps and aerial field verification, has been the Change Detection System developed under this contract. In comparison to alternative means of monitoring land development alterations and enforcing Coastal Zone Management regulations, this ERTS based system is both effective and inexpensive. The nominal cost of ERTS data is resultant from the cost sharing system among many users. Procurement of small scale aerial photography every 18 days is, of course, prohibitively expensive and would also reduce efficiency because of inundation by masses of data. ERTS imagery is only limited by meteorological conditions at the time of the overflight (a non-controllable parameter). This investigation has proven that monitoring landscape changes is still possible given other than cloud free conditions and further investigations into computer assisted analysis will no doubt develop cloud subtraction/recognition techniques to reduce the number of false alarms likely to be caused by the presence of scattered cumulus clouds.

Given an operational status permitting real time data availability, prompt interpretation and field verification would be possible, and the ERTS based Change Detection System would then provide the State of New Jersey with an inventory of landscape changes (ecological, seasonal, cultural) within short time frame (18 days). Areas in which changes have occurred have been detected experimentally down to 400 feet square (400' x 400'). This technique on a real time operational basis would greatly aid in reinforcement and regulation of New Jersey's Coastal Area Facilities Review Act.

ERTS imagery was routinely used during this investigation to monitor the effects of offshore waste disposal. The data prepared gave NJDEP an introductory environmental monitoring program which served to document and assess both the short and long term effects of ocean dumping. The results of these analyses have shown that actual dumps do not always coincide with designated and approved dumping sites and that the predominent dispersion and movement of relict (imaged) dumps has been found to be southwest towards the New Jersey shoreline. The dump site overlay products have provided useful information for the establishment of water quality sampling criteria applicable to the disposal of waste materials and for identifying pollution problem areas that require further investigation by NJDEP or EPA personnel. ERTS-1 has proven to be a valuable means of monitoring compliance with ocean waste disposal regulations in the New York Bight Area.

ERTS analyses proved very useful in monitoring large scale circulation patterns in the nearshore zone, and ERTS and aircraft data together were found useful for potential long term monitoring of the State's ocean outfall system. Through this ERTS experiment, information was developed about nearshore circulation characteristics that was not previously known to NJDEP resource managers.

The feasibility of using ERTS imagery to provide the information needed by NJDEP for shore protection planning (including allocation of funds) was investigated. It was determined that, even though it is possible to detect large shoreline positional changes, the spatial resolution of ERTS must be improved before subtle shoreline changes can be detected and monitored.

Because ERTS data alone could not provide the necessary resource information, a more conventional approach was used. Shoreline data were quantified from low altitude aerial photographs to demonstrate a method of data analysis that could be used as input to management decision models.

Conclusions drawn from the Shore Erosion case study indicate that in the northern test area (developed beach) erosion has occurred more often, is generally more severe, and the beach is slower to recover than in the southern test area (natural beach). From these data, it appears that it may be possible to define areas most likely to experience further erosion. This is not, strictly speaking, a statistical prediction but rather an assumption that a recognized trend will continue. The assumption of continued erosion in areas that have at one time experienced severe erosion is supported by the relationships between beach width and energy dispersion. As a beach erodes, wave energy is concentrated on a narrower beach surface. High wave energy per unit area subsequently results in accelerated erosion. These analyses have direct operational value to NJDEP with respect to geographical allocations of yearly funds for shore protection and may impact management decisions for future priorities as to the philosophy of shore protection.

Further, the investigators believe they have met the principal objective of the NASA ERTS program using ERTS data for the protection and management of the coastal zone. Information products produced during this investigation have led to improved operational efficiency within the State through their use within various divisions of the NJDEP. The NJDEP believes ERTS to be of greatest value to the State in the future in terms of: (1) Land Use Development Change Detection, (2) Waterfowl Game Management, (3) Offshore Waste Disposal, and (4) Floodplains Mapping.

The investigators note a need for more speedy receipt of ERTS imagery at somewhat higher spatial resolutions and with greater frequency of coverage to increase the value of ERTS analytical products. Many of the products developed would have a greater impact on management decisions if the ERTS system were improved in the above-mentioned manner.

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APPENDIX A

1. KEY - AREA DESCRIPTOR

Type of Area Surrounding Change Site

A. Forested area

B. Wetland/marsh

C. Mixed land use (forest/urban/suburban/agricultural)

D. Barrier island - natural undeveloped

E. Barrier island - developed

F. Adjacent to existing development

G. Urban area

H. Suburban area

I. Agricultural

J. Mineral extraction

K. Transportation networks

L. Open fields w/low vegetation (grasses, shrubs, etc.)

2. KEY - TYPE OF CHANGE

Type of Change Activity Present

I. Cultural changes

a) land clearing for development subdivision

b) land filling for development subdivision

c) agricultural

d) land alteration for mineral extraction

e) solid waste disposal

f) dredge spoil disposal

g) diking and water impoundment

h) transportation network

i) land alteration for development

II. Ecological Changes

a) successional old field

b) wildlife induced (beaver dams)

c) tidal stages causing differences in innundation

d) erosion accretion of coastline

III. Seasonal Changes

a) forested areas (deciduous trees)

b) snow covered and frozen areas

c) fields and shrubbed areas

d) wetland area (dormant stages)

e) mixed stand - hardwood and coniferous

3. KEY - ERTS DETECTION CONFIRMED ACCURACY OF DELINEATION

A) Accurate

B) Fairly Accurate

C) Inaccurate

4. KEY - ERTS DETECTION UNCONFIRMED POSSIBLE CAUSE

a) Cloud cover

b) seasonal vegetative differences (wetlands - uplands)

c) tidal differences

d) unexplained

e) interpretor error

f) imagery defect

APPENDIX B

The high water line and dune line were used to determine rates of beach erosion and accretion because both were relatively easy to identify on aerial photographs and both respond to changes in wave conditions, sediment supply and certain practices of environmental manipulation. The high water line appears as a boundary on aerial photographs between light and dark areas on the beach. This sharp contrast is a result of the higher water content of the sand in the swash zone compared with the backshore area. The high water line is independent of the tide level to the extent that it does not transgress or regress with the rise and fall of each tide; it is established during high tide at the point of repeated inundation by wave runup. The positional change of the high water line is dependent upon the natural or artificial addition or removal of sand and the change of slope of the beach face with or without a net material loss. Because sand removal is of primary concern in coastal zone problems, and because the high water line reacts in response to this condition, the high water line is a suitable indicator of shoreline change.

The dune line is similarly responsive to erosion and deposition and, therefore, is used as a second indication of shoreline change. This line is defined as the point of maximum slope change and is often marked by the seaward most extent of dune vegetation or an erosion scarp. Sand fences that are used to trap sand can be considered the dune line of incipient dunes when well established dunes are not present. It is difficult to identify a dune line in the absence of dune vegetation, erosion scarps or sand fences, and in such cases, stereoscopic viewing of the area is necessary to create the illusion of relief, thereby making it possible to locate the maximum slope break. The dune line is a relatively stable feature; changes in the dune line are indicative of extreme conditions such as severe storms, artificial manipulation of the dune line by either sand removal or replenishment and prolonged intense winds which may blow sand from the beach face to the dunes.

In the northern test section some dunes and embankments exist, but most of the coast is fortified by stone or concrete bulkheads. In these areas measurements were still made and rates were calculated. Stone bulkheads under most conditions are unlikely to be eroded. However, by making these measurements, additions to or removal of these structures can be detected. Also, changes in beach sand levels can be detected. When the sand level changes, the boundary line of the sand and the sloping bulkhead face appears to be displaced inland or seaward when observed on a vertical aerial photograph.

The position of each feature (1) (high water line; (2) dune line; or (3) bulkhead) was measured on aerial photographs taken by the NJDEP in the years 1954, 1957, 1960, 1961, 1962, 1963, 1966, 1969 and 1971. The scale of these photographs is approximately 1:9,600. However, to determine the exact position of a feature relative to a reference point, it was necessary to calculate the scale of each photograph.[B1/]

Even though the time intervals varied slightly the rates computed could still be compared by expressing the rate of positional change in feet per year. However, those rates that represent beach changes before and after the Great March storm of 1962 are actually projected rates in feet per year, because the time interval between successive photographs was less than one year.

The position of the features (high water line, dune line or bulkhead) were measured relative to the 84 fixed reference points which were stations spaced approximately 2,000 feet apart (ground distance).

The 84 fixed reference points were selected as points that could be easily identified on aerial photographs taken during the years mentioned above, and as points that would not have moved since 1954; for example, the corner of a building visible on the 1954 and the 1971 photo and on all photographs for the years between 1954 and 1971.

B1/ The measurement of the three features mentioned above and the determination of scale was accomplished using a precision instrument which has a capability of measuring to .001". On photographs with scale of 1 inch equals 800 feet, ground distances of 0.8 feet can be measured; an acceptable degree of precision in monitoring shoreline changes. To reduce the error due to photographic distortion, reference points were selected as close to the nadir (center of the photo) as possible. Random measurement errors were minimized by spot checking the measured points and by remeasuring points which the computer identified as having an unusually high rate of change.

Because ground control points do not appear on all photographs, scale determinations had to be made by a ratioing process. This process involved the measurement of the distance between two arbitrary points common to a photo of known scale and one with unknown scale. For example, Photo A has a scale of 1 inch = 815 feet and the distance between two arbitrary points X and Y on Photo A is 1.671 inches. To determine the scale of Photo B which has a distance of 1.628 inches between points X and Y, an inverse proportion must be used:

$$\frac{\text{SCALE OF PHOTO A } 815}{\text{SCALE OF PHOTO B } X} = \frac{\text{Db } 1.628}{\text{Da } 1.671} \qquad (1)$$

$$S = 836$$

When the scale of Photo B is known, the scale of Photo C can be calculated in a similar fashion after measuring the distance between two points common to Photos B and C. The scale of all 1969 photographs from Highland Beach Bridge to Manasquan Inlet were determined by this method. The scales of photographs for all other years were calculated relative to the 1969 photos by computer using a ratio process.

The rates of erosion and accretion are calculated (Formula 2) by determining the change in distance from the reference point to the feature of interest, then multiplying by the scale of the photo and dividing by the time interval, in years, between measurements. The rates are presented in graphic and tabular form in Appendix D.

$$Rt_{k_{i_j}} = \frac{S_K (f_{ki} - f_{kj})}{Y_{ij}}$$

Rt = Rate of positional change

S = Scale factor of the photograph (2)

f = Coastal zone feature
high water line or dune line

Y = The time interval between measurements

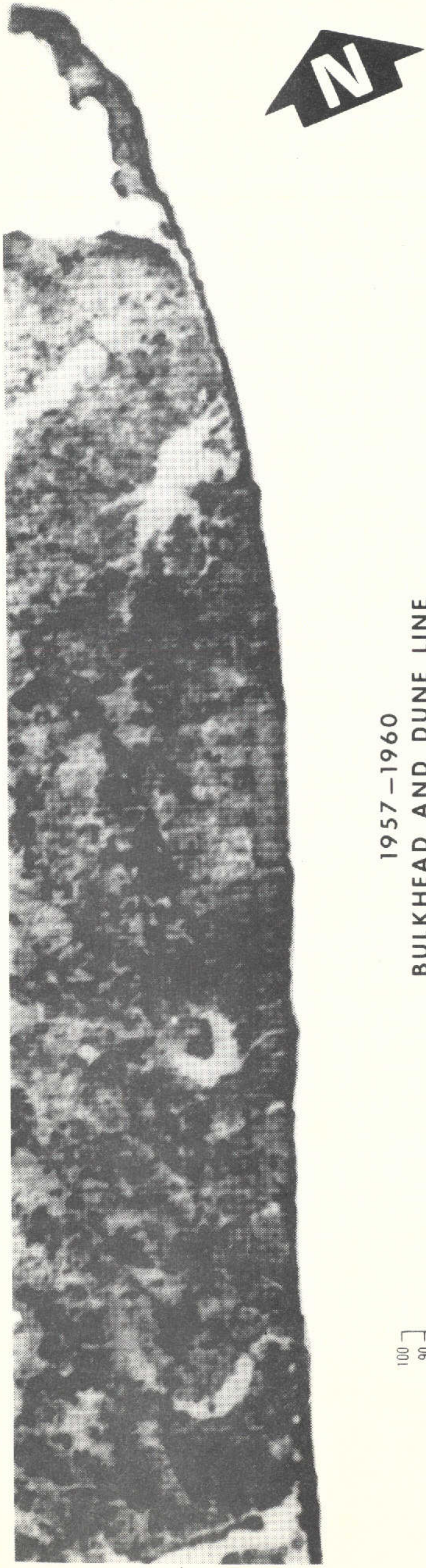
i = The years being considered (54, 57 . . . 69)

j = i + 1 (57, 60 . . . 71)

k = Station number (reference point number)
Number of test sites

Although it may be more difficult, it is still possible to detect trends of erosion or accretion between several time intervals by observing the record of erosion and accretion on all graphs at one station, a group of stations or between different areas of the coast such as the difference between the northern and southern test section in this study.

Examination of the graphs reveals many sharp and extreme peaks which indicate that extremely high rates of erosion or accretion occurred during a specific time interval. In Figure 39 (1957-1960 time interval) two peaks on the high water line graph are very prominent, one (station 36) is accretive and the other (station 37) is erosional. In fact the values that appear in the 1957-1960 high water line table (northern section) indicate that at station 36, 141 feet of accretion occurred in



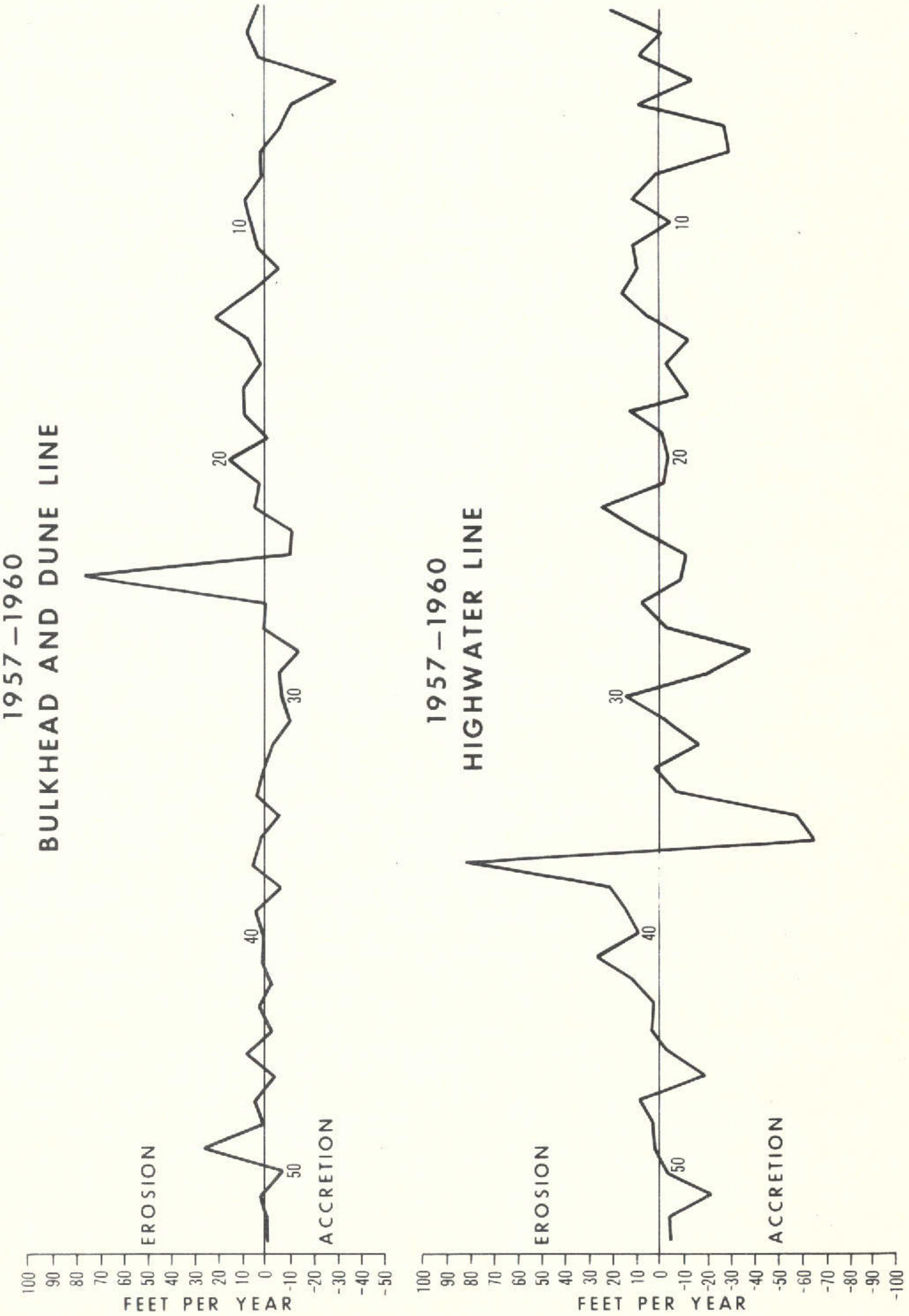


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FIGURE 39 RATE OF CHANGE GRAPH, NORTHERN TEST SECTION 1957-1960

2.16 years, a rate of 65.2 feet per year; at station 37, 178 feet of erosion occurred in 2.16 years, a rate of 82.68 feet per year. These rates are indeed extreme and even more important because these points are only 2,000 feet apart! Figure 40 verifies the extreme erosion and accretion values at stations 36 and 37. In the 1957 photograph a large fillet of sand is evident on the updrift side of the jetty at Shark River inlet. At station 36 in the same year the high water line is about 100 feet from the boardwalk. But in the 1960 photograph the high water line at station 37 has receded and at station 36, it moved seaward. This event is recorded as two sharp peaks on the 1957-1960 rate of change graph.

The change at station 37 appears to be the result of artificial sand removal. The reason for removal could well have been for nourishment of the beach at station 36, this would account for the high accretion rate. If this indeed occurred this analysis provides a historical, quantitative record of the effectiveness of the project and compared to the cost, a cost-effectiveness ratio could be determined. However, the investigators were unable to obtain the costs of this particular engineering project.

Figure 41 illustrates a large positional change of the high water line (99 feet, rate: 66 feet/year) at station 7 during the 1969-1971 period and Figure 42 illustrates a similar situation. From the 1969-1971 graph, the rate of high

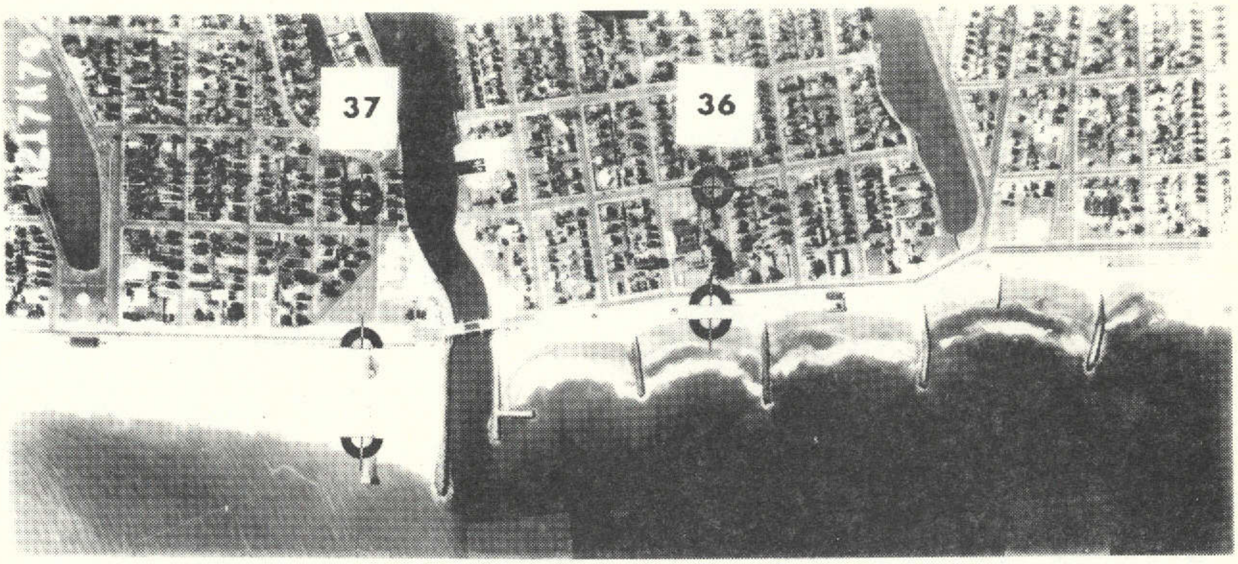
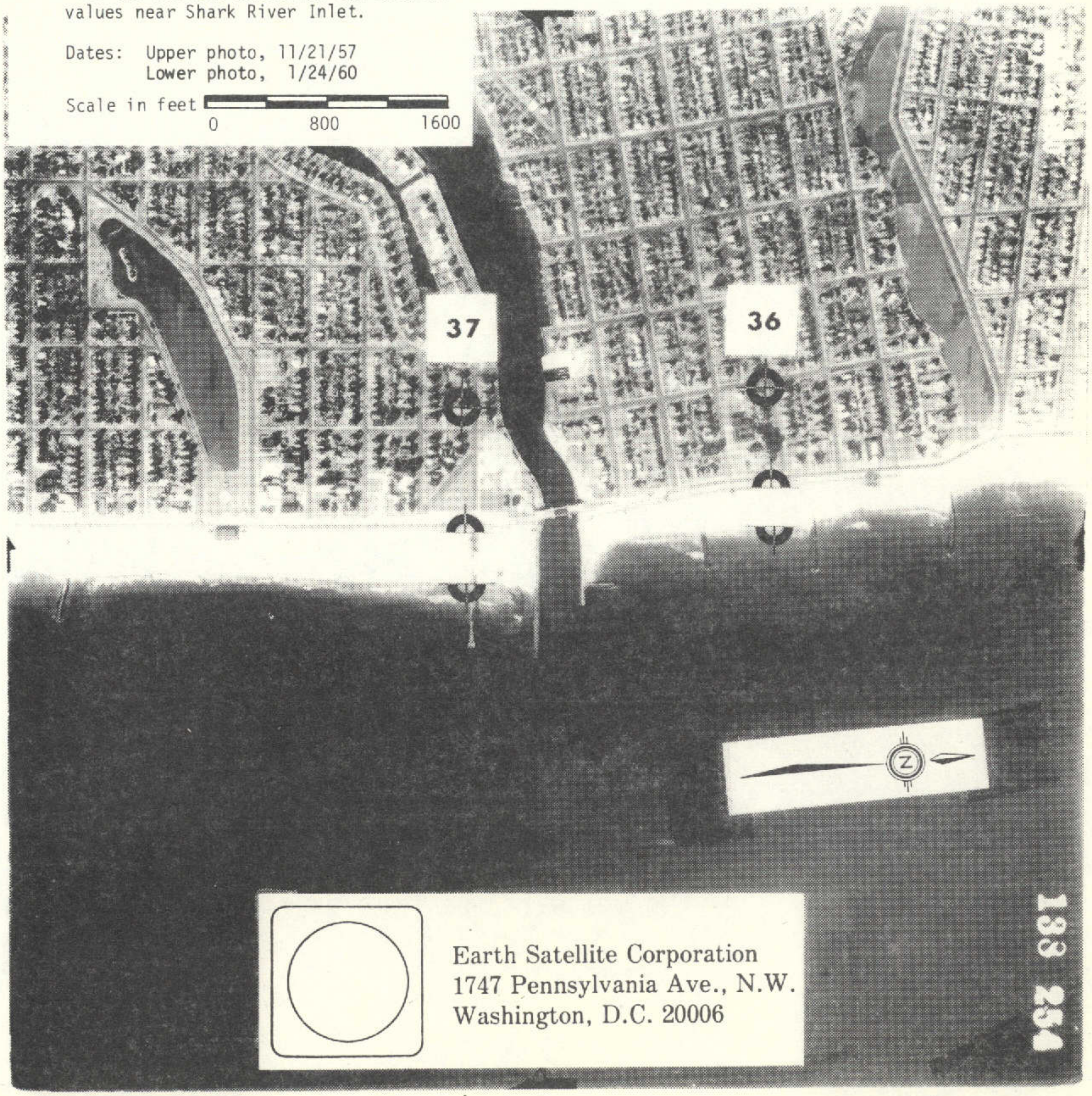


FIGURE 40

Note the extreme accretion and erosion values near Shark River Inlet.

Dates: Upper photo, 11/21/57
Lower photo, 1/24/60

Scale in feet 0 800 1600



water line erosion at station 21 is obviously not as high as the rate at station 7; but it is important to note that even though this portion of the coast is characterized by bulkheads and closely spaced groins, which are intended to encourage sediment accumulation, high rates of erosion still occur.

Figure 43 illustrates a one mile portion of the northern test section that experienced the highest rate of high water line erosion (164 ft., 9.72 feet/year) during the 17 years between 1954-1971, despite the construction of an extensive groin system. It is obvious that the groin system did not improve the beach, however, it is difficult to determine how much erosion the groins did prevent.

Figures 41, 42, and 43 illustrate large changes only in the high water line in the northern test section. The rates of change for the dune line or bulkhead may be deceiving in the northern section if it is not known which feature is being measured, dune line or bulkhead. As previously noted, it is unlikely that the bulkhead line will move unless the structure is destroyed by waves, or collapses due to undermining by waves. Addition of stone or other reinforcement materials are detectable and do appear as accretion of the bulkhead. What is deceiving about erosion and accretion at a sloping face bulkhead is that there is an inverse relationship between beach changes and the positional change of the sand-bulkhead boundary line. At a bulkhead sloping seaward, a rise in the

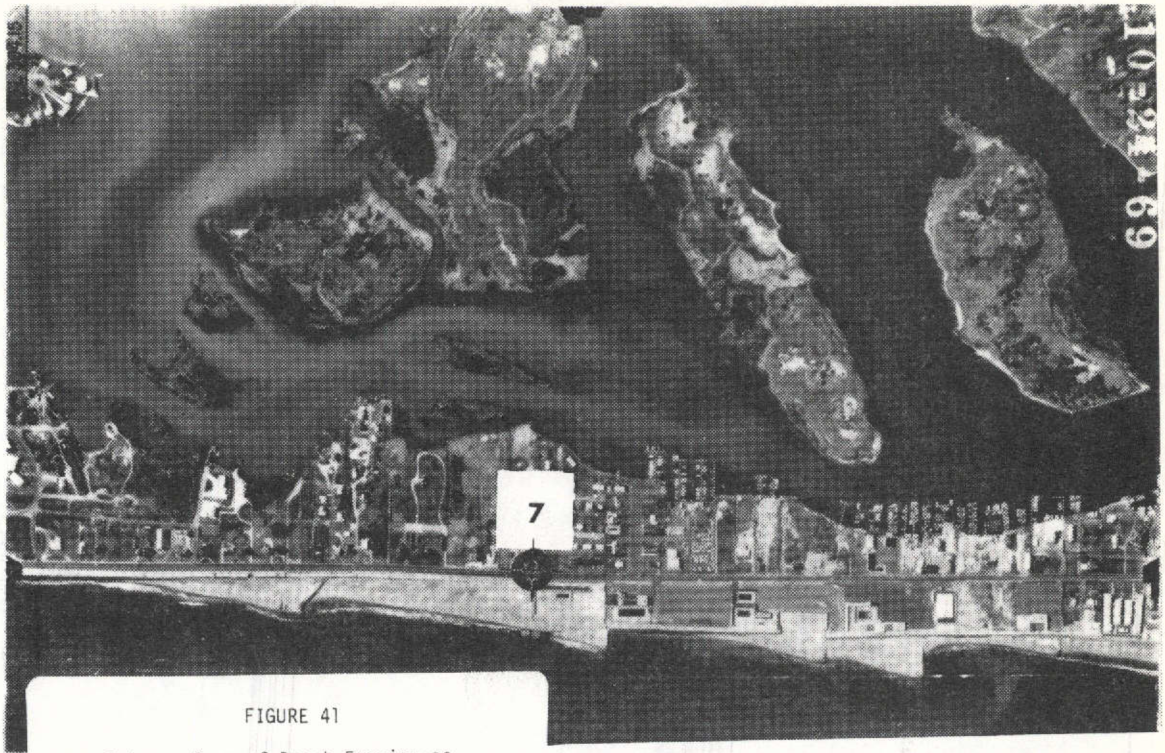
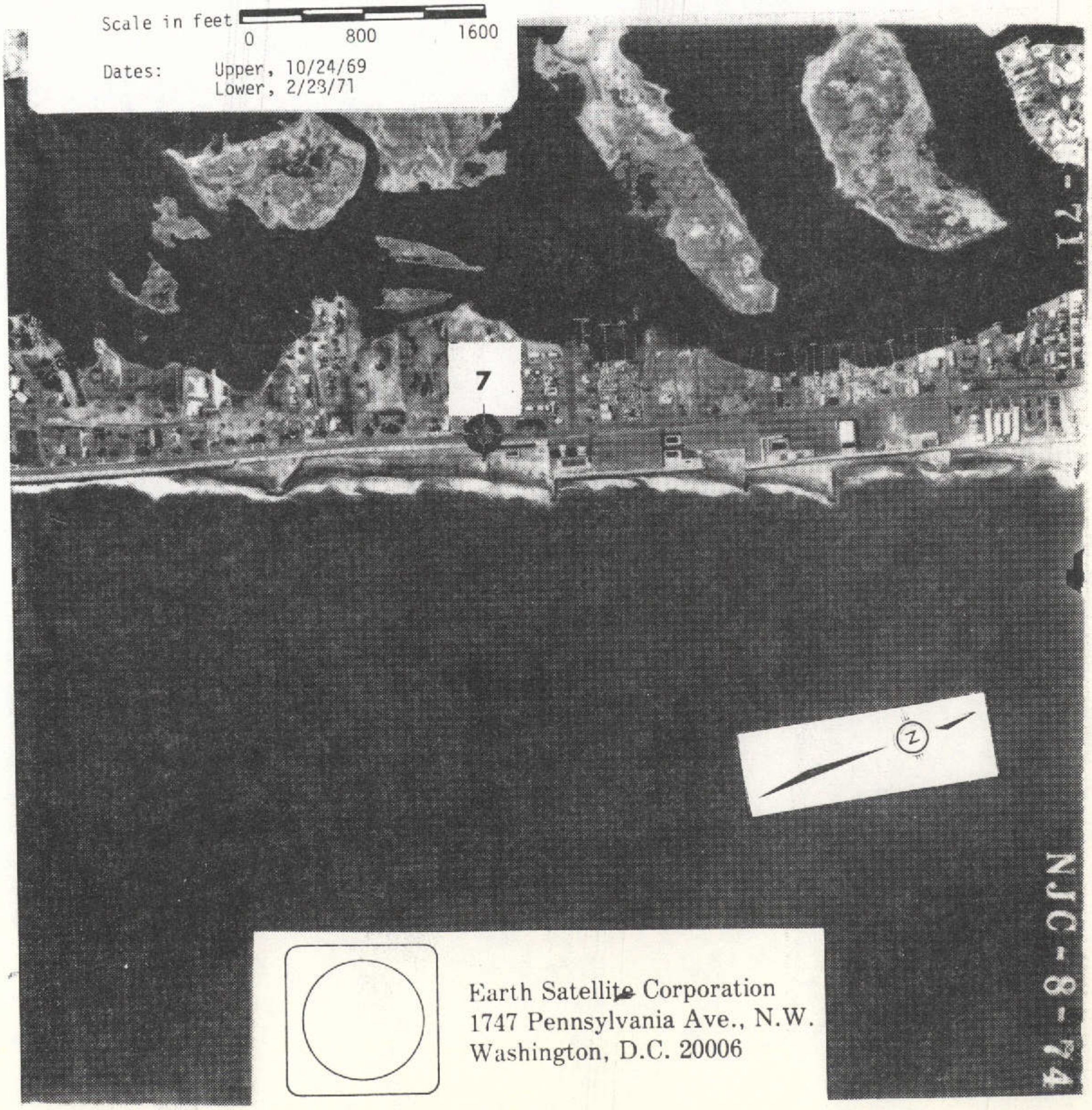


FIGURE 41

Extreme Case of Beach Erosion as
Noted on Aerial Photographs of
the Northern New Jersey Coast

Scale in feet 0 800 1600

Dates: Upper, 10/24/69
Lower, 2/23/71



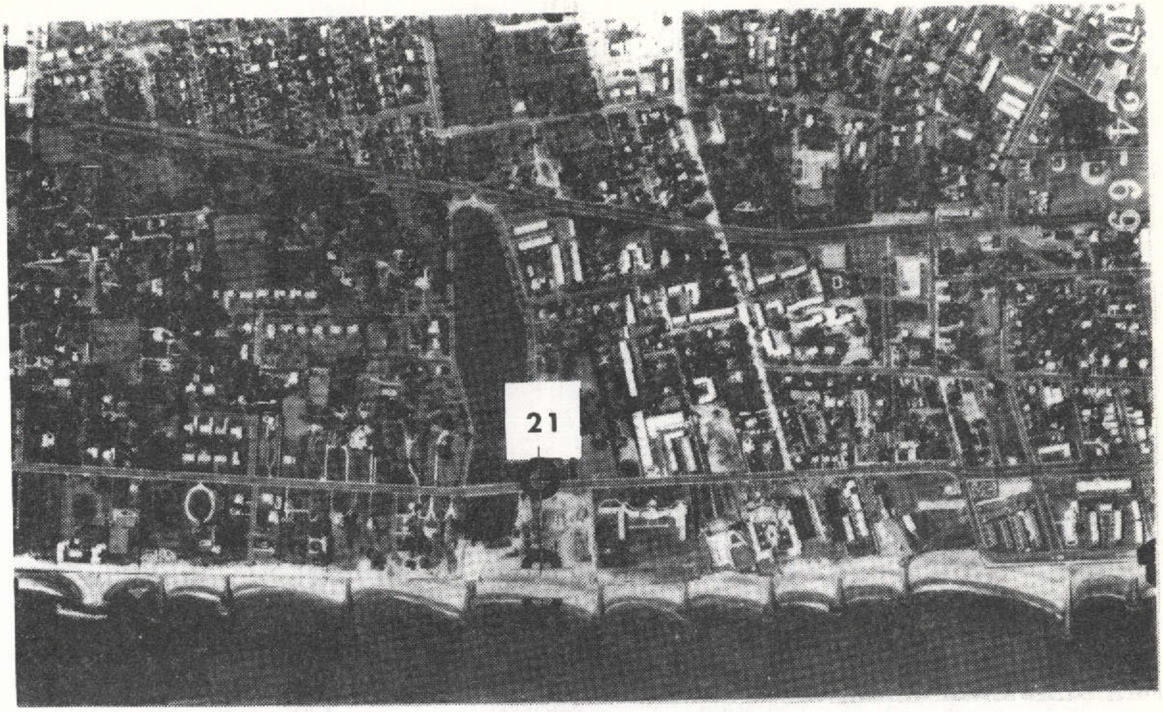
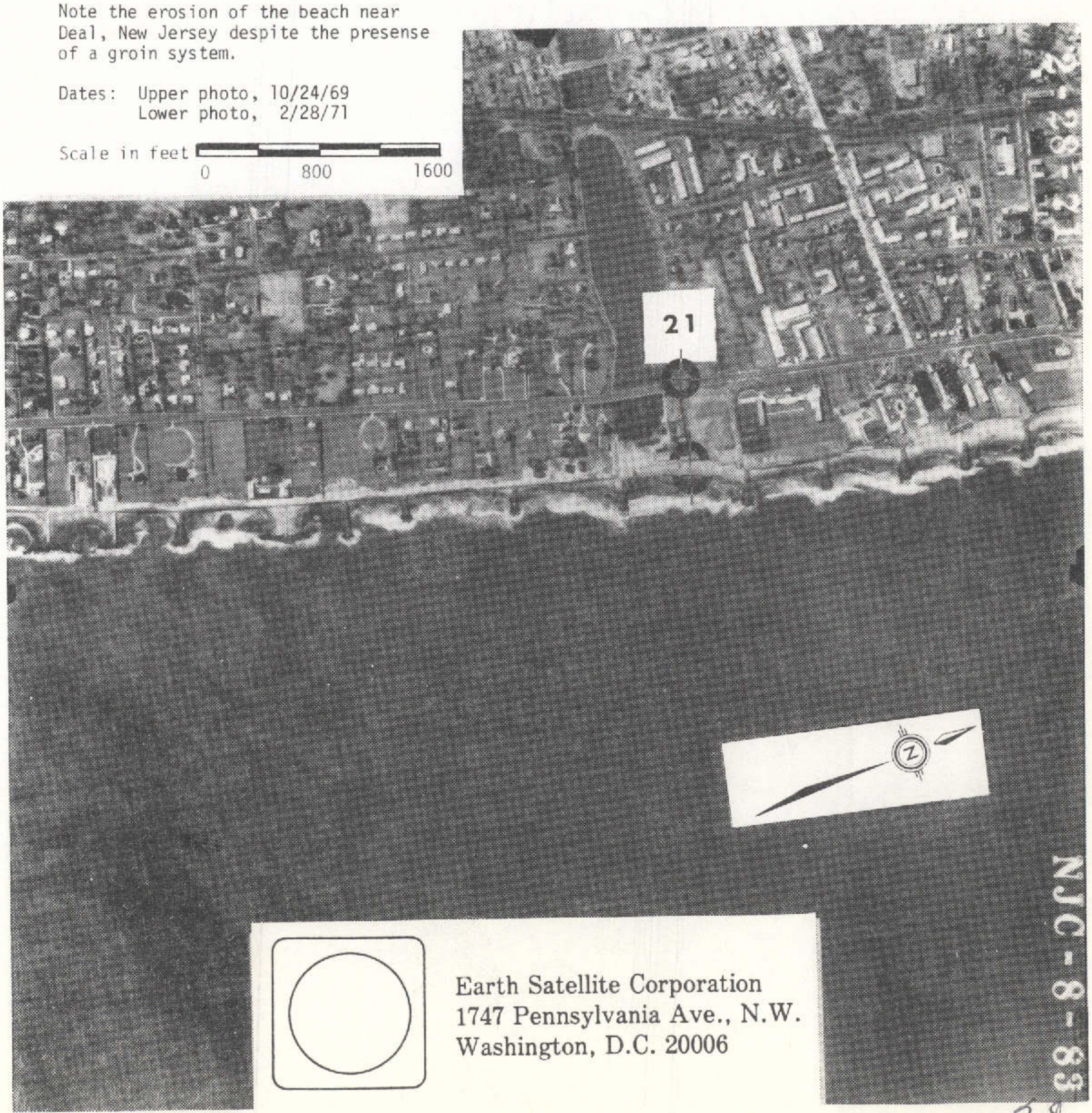


FIGURE 42

Note the erosion of the beach near Deal, New Jersey despite the presense of a groin system.

Dates: Upper photo, 10/24/69
Lower photo, 2/28/71

Scale in feet 0 800 1600



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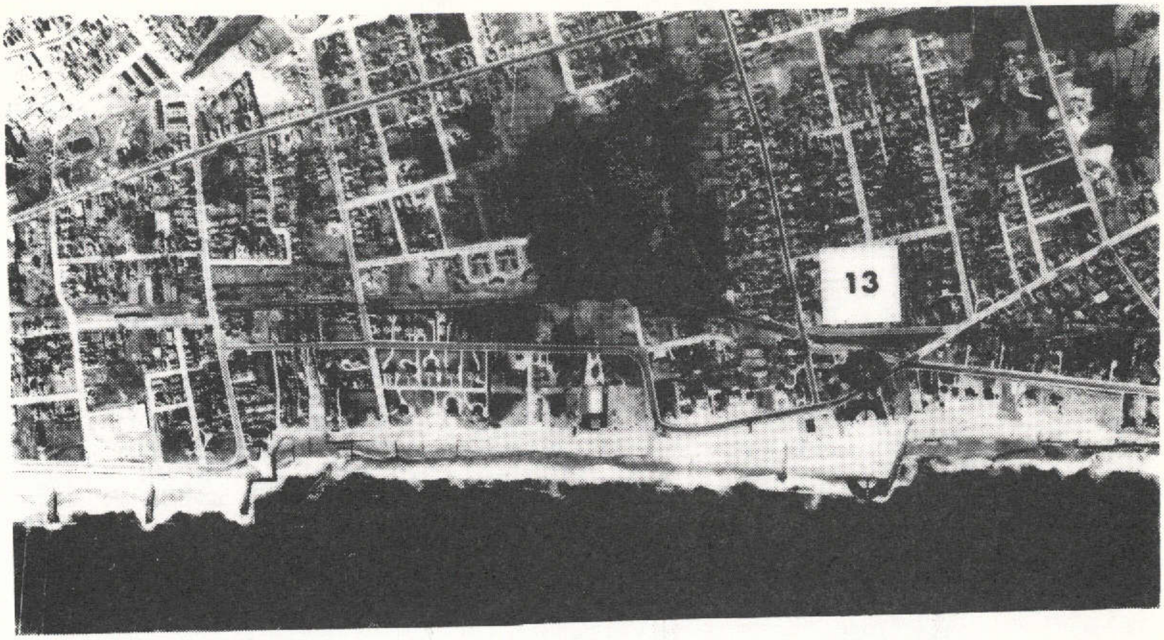


FIGURE 43

The littoral current moves from south to north. The three large groins built immediately updrift of Station 13 are preventing sand from reaching the beach at Station 13.

Dates: Upper photo, 4/30/54
Lower photo, 2/28/71

Scale in feet 0 800 1600

sand level on the beach (accretion) causes an inland positional displacement of the sand-bulkhead boundary line because less of the bulkhead is visible. Beach accretion therefore appears to correspond to bulkhead erosion at a sloping face bulkhead. The reverse is also true, erosion of the beach produces a seaward displacement of the sand-bulkhead interface, hence there is apparent accretion of the sand-bulkhead interface. This phenomenon is illustrated in Figure 44. The high water line at station 1 eroded 80 feet between October 10, 1969 and February 2, 1971 while the bulkhead had an apparent accretion of 4 feet. The bulkhead did not move but when the sand level went down the sand-bulkhead interface was displaced seaward. Even though bulkheads do not erode and accrete like a dune might, it is important to calculate their apparent rates of change. These rates are useful in monitoring structural alteration of the bulkhead either because of repair or wave damage.

The rates of erosion or accretion of the dune line or unprotected banks were more readily interpreted because the rates do indicate actual erosion or accretion.

In the southern test section extreme erosion of the high water line and dune line occurred at station 80 between November 1961 and May 1962 (Figure 45). The Great March Storm of 1962 was responsible for extreme erosion along the entire coast of New Jersey. The rates of erosion were so high at the

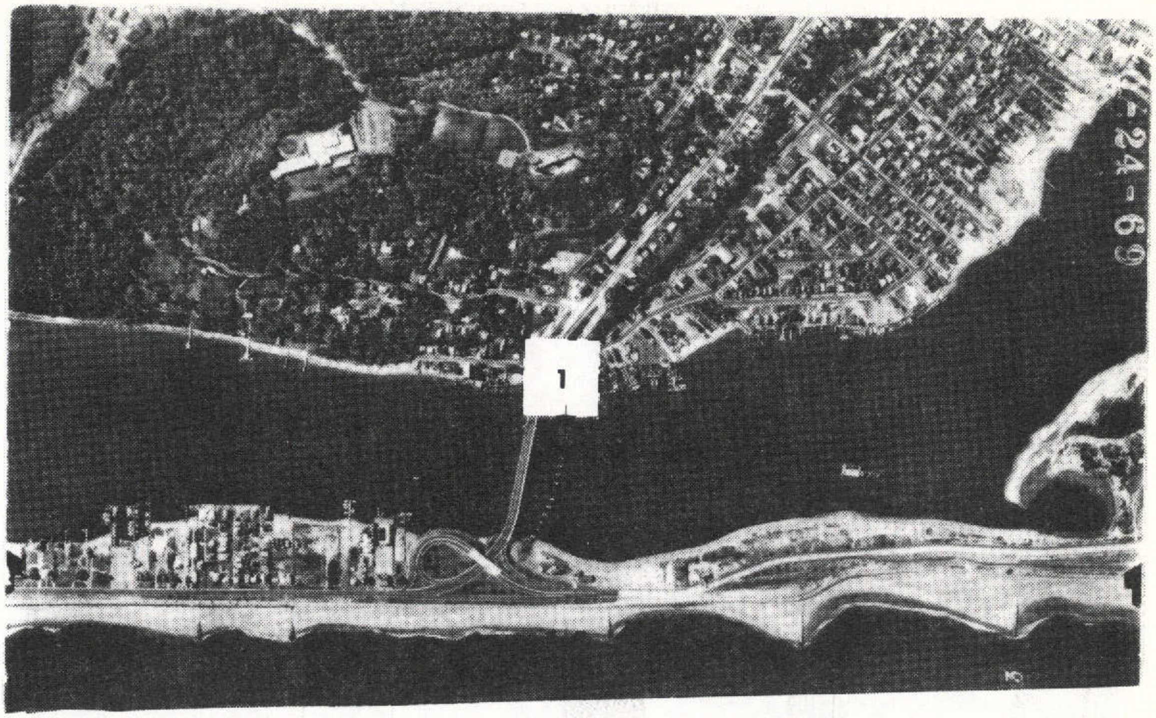
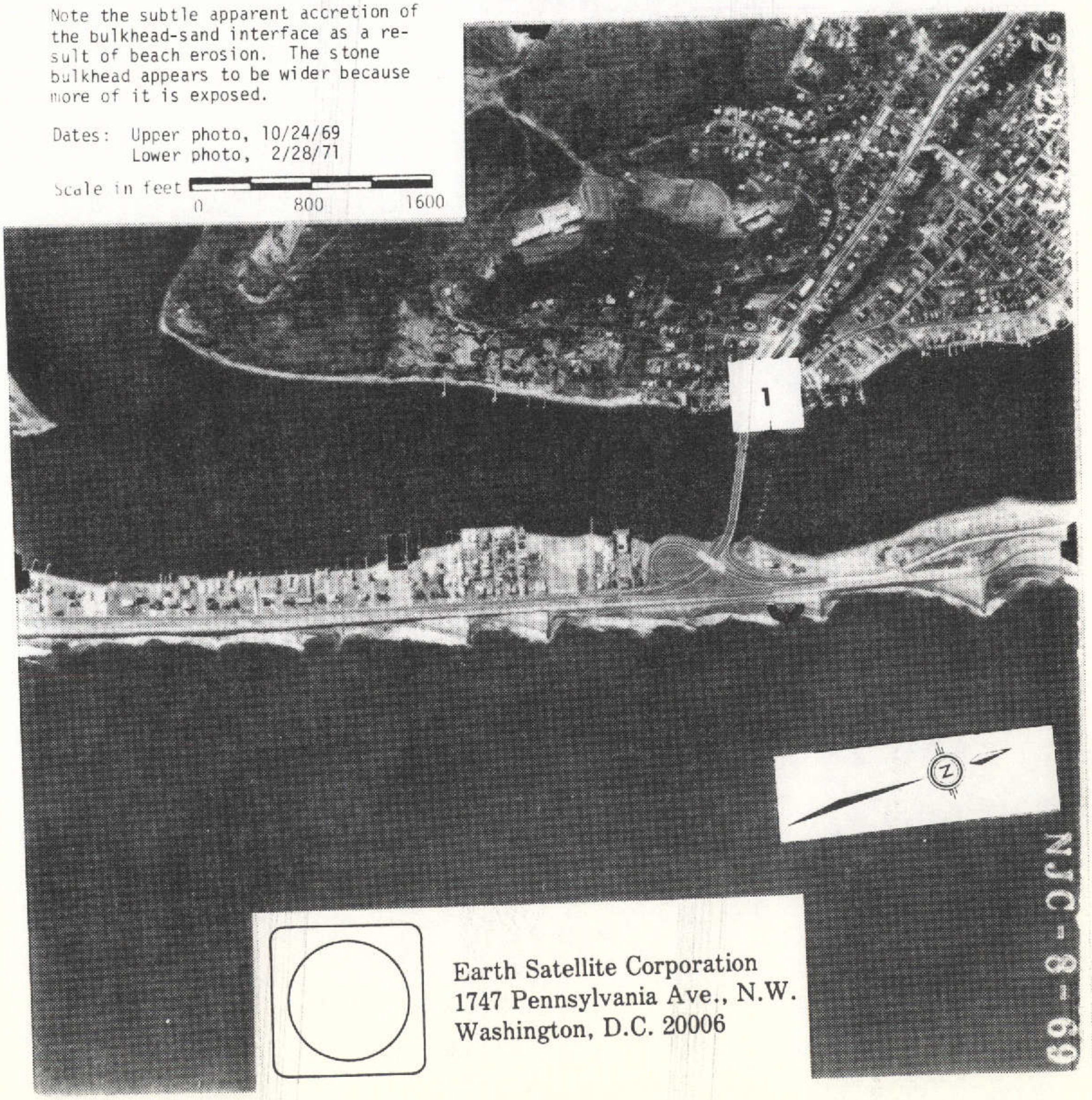


FIGURE 44

Note the subtle apparent accretion of the bulkhead-sand interface as a result of beach erosion. The stone bulkhead appears to be wider because more of it is exposed.

Dates: Upper photo, 10/24/69
Lower photo, 2/28/71

Scale in feet 0 800 1600



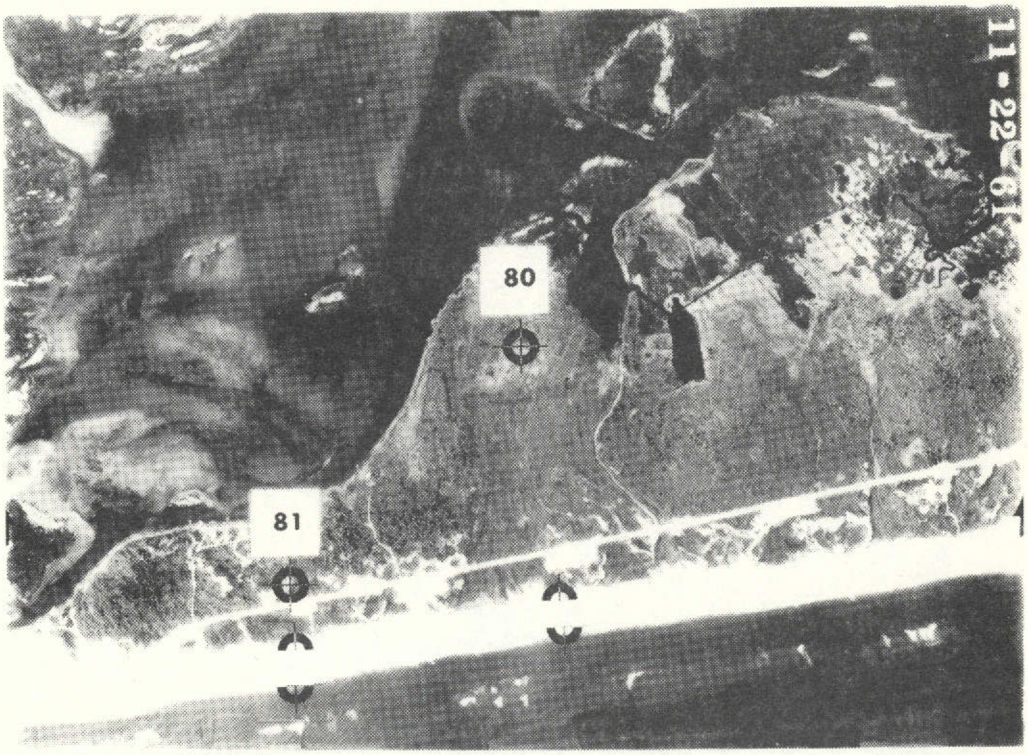
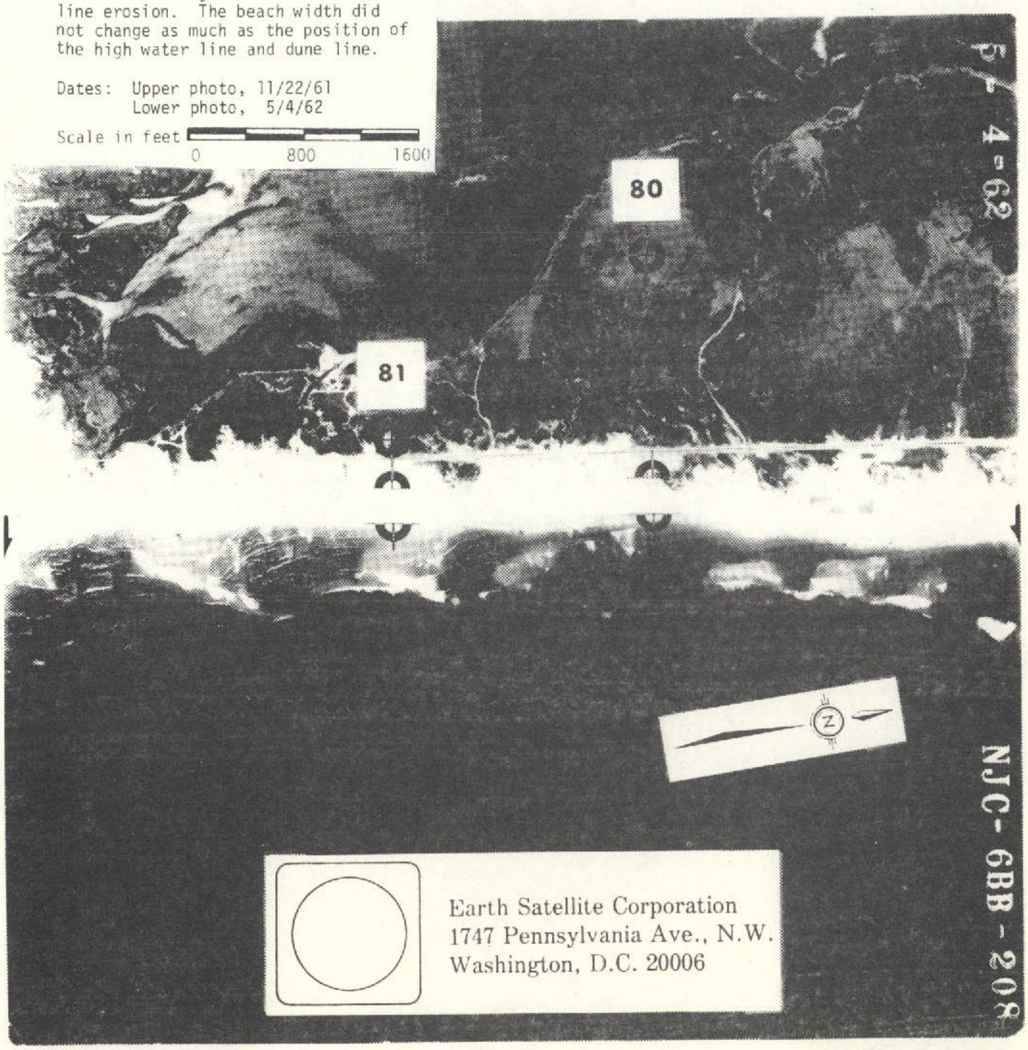


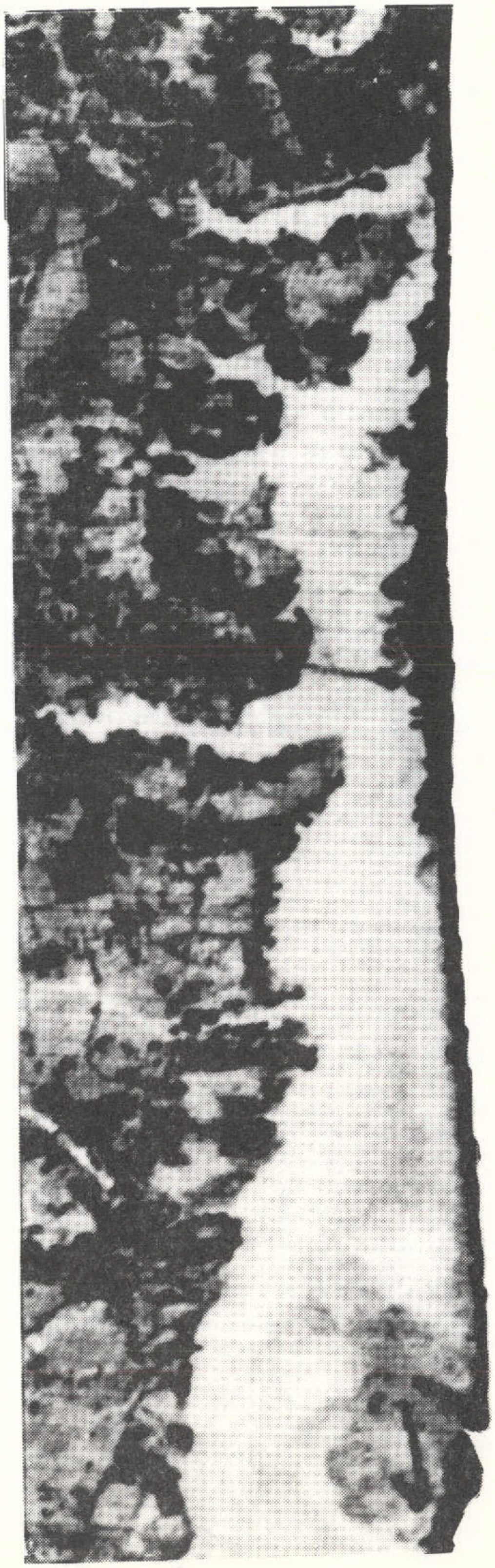
FIGURE 45

Note extreme high water line and dune line erosion. The beach width did not change as much as the position of the high water line and dune line.

Dates: Upper photo, 11/22/61
Lower photo, 5/4/62

Scale in feet 0 800 1600





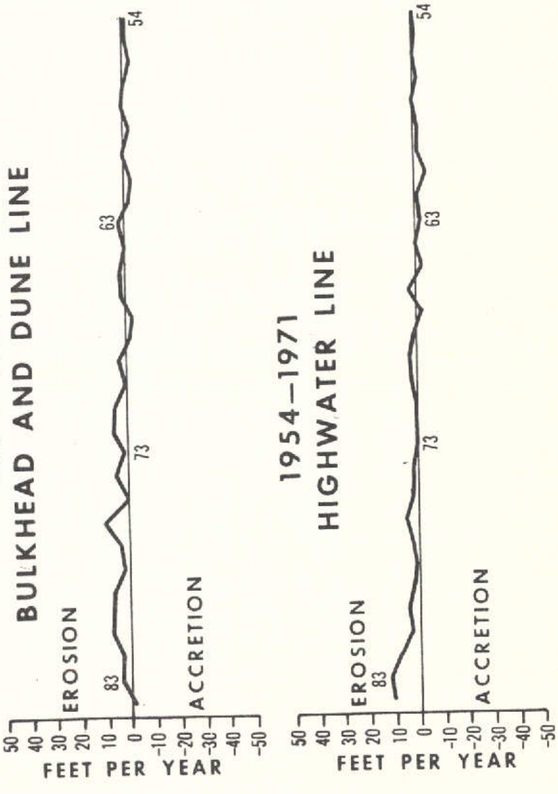


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FIGURE 46
RATE OF CHANGE GRAPH, SOUTHERN TEST SECTION 1954 - 1971

dune line in the southern section that a graph was not plotted because most values were off the scale. In fact on the 1961-1962 high water line graph, station 80 had a projected erosion rate of 154 feet per year, and the dune line had a projected rate of 341 feet per year! These rates of course are not real because the time interval between the aerial photographs was about 6 months and the amount of erosion or accretion was extrapolated over a period of one year. To analyze large but short lived beach changes such as those that ocurred during the March 1962 storm, rates of change may be expressed in feet per month.

In the dune line graph representing the composite rates of change for the 17 year period between 1954 and 1971 in the southern section there is one prominent erosion peak (Figure 46). The actual rate is 9.6 feet per year which represents a change in position of the dune line of 163 feet inland in 17 years. The high water line eroded 83 feet, or half the amount of the dune line.

The rate of change graphs are helpful in obtaining rapid qualitative information on erosion and accretion events along a coast. When the rate of change graphs (Figure 46) are studied together the tables of rates, and the aerial photographs, it is possible to develop an intuitive impression of erosional trends for areas or for specific stations. It may, however, be difficult to visualize some trends without tabular or graphic summaries of the erosion and accretion data.

Figure 47 is a histogram of the mean rates of change of all stations in both test sections for all time intervals. Looking at the first six time intervals, beginning at the left, it is apparent that periods of general erosion and accretion occur alternately with erosion having higher values. The composite mean rates for the entire time interval 1954-1971 indicate that the overall trend was erosion in both test sections.

In the three time intervals documenting the period before and after the storm of 1962, some important relationships must be noted. In the southern test section, during the 1960-61 interval, there was high water line erosion and dune line accretion. One possible interpretation is that the dune, due to extensive stabilization efforts, experienced accretion at the expense of the foreshore, where the high water line is located. The process of sediment transport from the foreshore to the dunes is discussed in Appendix C. The opposing relationship between the erosion and accretion values is understandable and perhaps predictable. Part of the large volume of sand eroded from the dunes between 1961-62 was deposited in the foreshore and offshore zones which had the effect of displacing the high water line seaward, indicating real accretion. After the storm (1962-63), sand that was deposited offshore during the storm was then deposited on the beach and subsequently transported to the dunes. Both the high water line and the dune line accreted during this time interval.

ALL MEAN RATES OF CHANGE

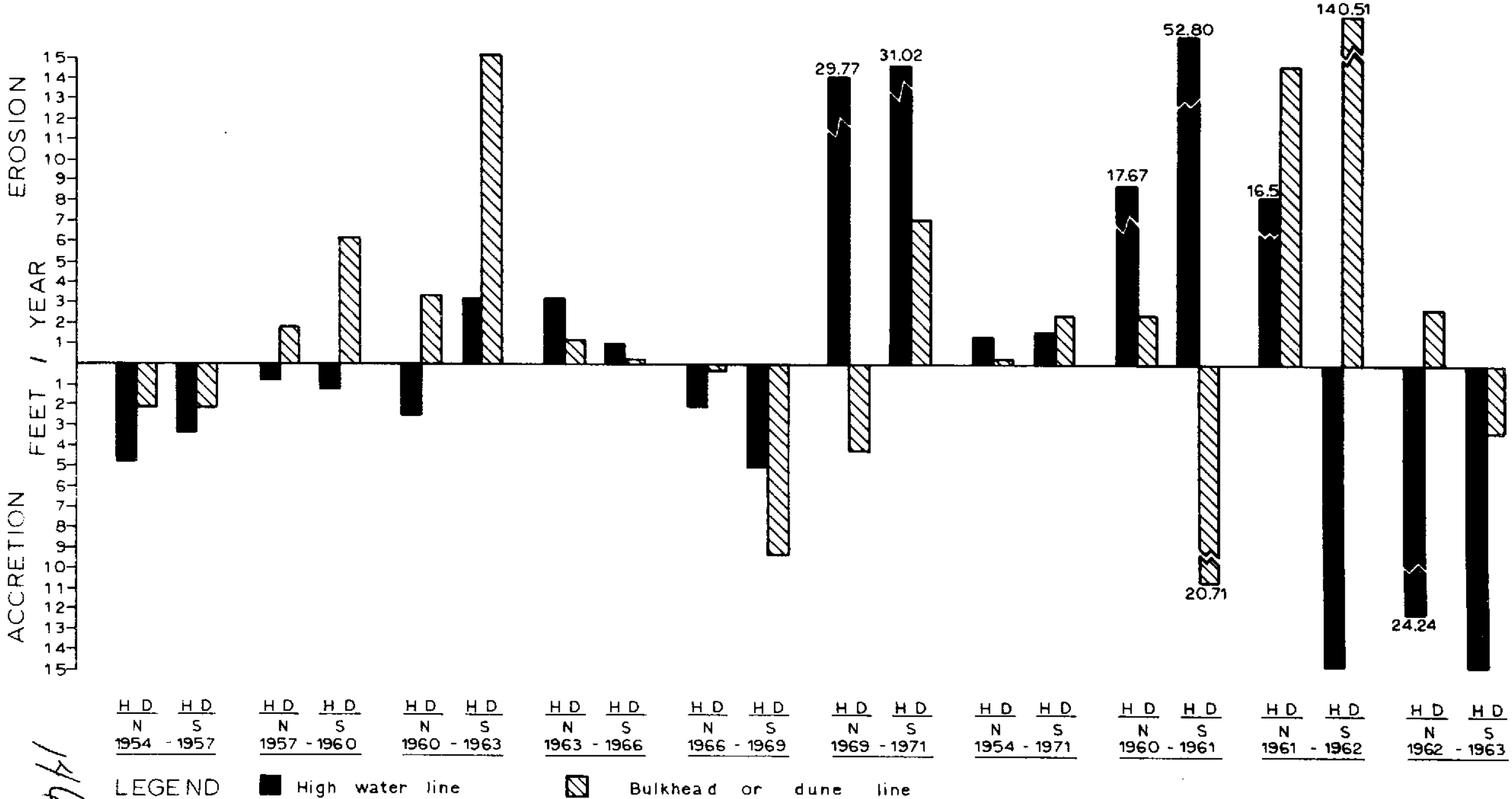

FIGURE 47

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The behavior of the beach in the northern test section is not the same as the beach in the southern section for several reasons, the more important being:[B2/]

- The beaches in the northern section are narrower than those in the southern section. At times waves may be reflected by the bulkhead which not only prevents deposition, but often encourages scour and erosion.

- When the process of erosion of the backshore and deposition in the foreshore and offshore zones occurs, a certain amount of sand is transported downdrift, as it does in the southern section. However, in the northern section the beaches with a sand deficit can less afford any sand loss than the beaches in the south can.

- Post storm accretion in the north cannot be predicted because of the sand deficits, and because artificial beach nourishment is used to restore certain beaches. Where sharp accretion peaks appear on the high water line rate graphs, beach filling operations should be suspected.

Another important measurement needed to plan shore projection projects is the beach width. It is calculated by substracting the distance between the reference point and the dune line from the distance between the reference point and the high water line. The importance of the beach width measurement is in its relationship to the high water line and dune line erosion rate. In order to evaluate erosion severity

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B2/ It is recognized that beach slope and mean grain size bear a cause and effect relationship with many beach processes. However, they are only two of several factors, such as wave and wind energy or sediment sources, that are manifested as positional changes of the high water line and dune line. Measurement of these beach conditions was beyond the scope of this investigation.

the mean ratio of erosion rate to beach width at each station for all years was calculated. When this ratio, called the change index, is small, the severity of erosion relative to beach width is low. As the value of the ratio approaches one, the erosion severity increases relative to beach width. If the ratio is greater than one, the entire beach system has moved inland; the high water line has eroded during the given time interval beyond the original positon of the dune line at the beginning of the time interval. This condition would indicate extremely severe erosion where perhaps a bulkhead or dune line has been destroyed.

Absolute values of erosion are important, but they do not yield a complete summary of beach conditions. A 100-foot beach can tolerate more erosion than a 20-foot beach. For example, if just the respective high water line erosion values were stated for thos two beaches, 10 feet and 5 feet, it would be logical to assume that by comparison the beach that experienced 10 feet of erosion experienced more severe erosion than the one that lost only 5 feet of beach. The fact is that when the erosion values are compared to the beach width, the 20-foot beach suffered more severe erosion than the 100-foot beach because the 20-foot beach was reduced by 25% while the 100-foot beach was reduced by only 10%. Figures 51, 52, 53 and 54 represent the graphic display of change indices calculated for the high water line at each station in both the northern

1939-1971 HIGH WATER LINE
EROSION INDEX NORTHERN TEST SECTION

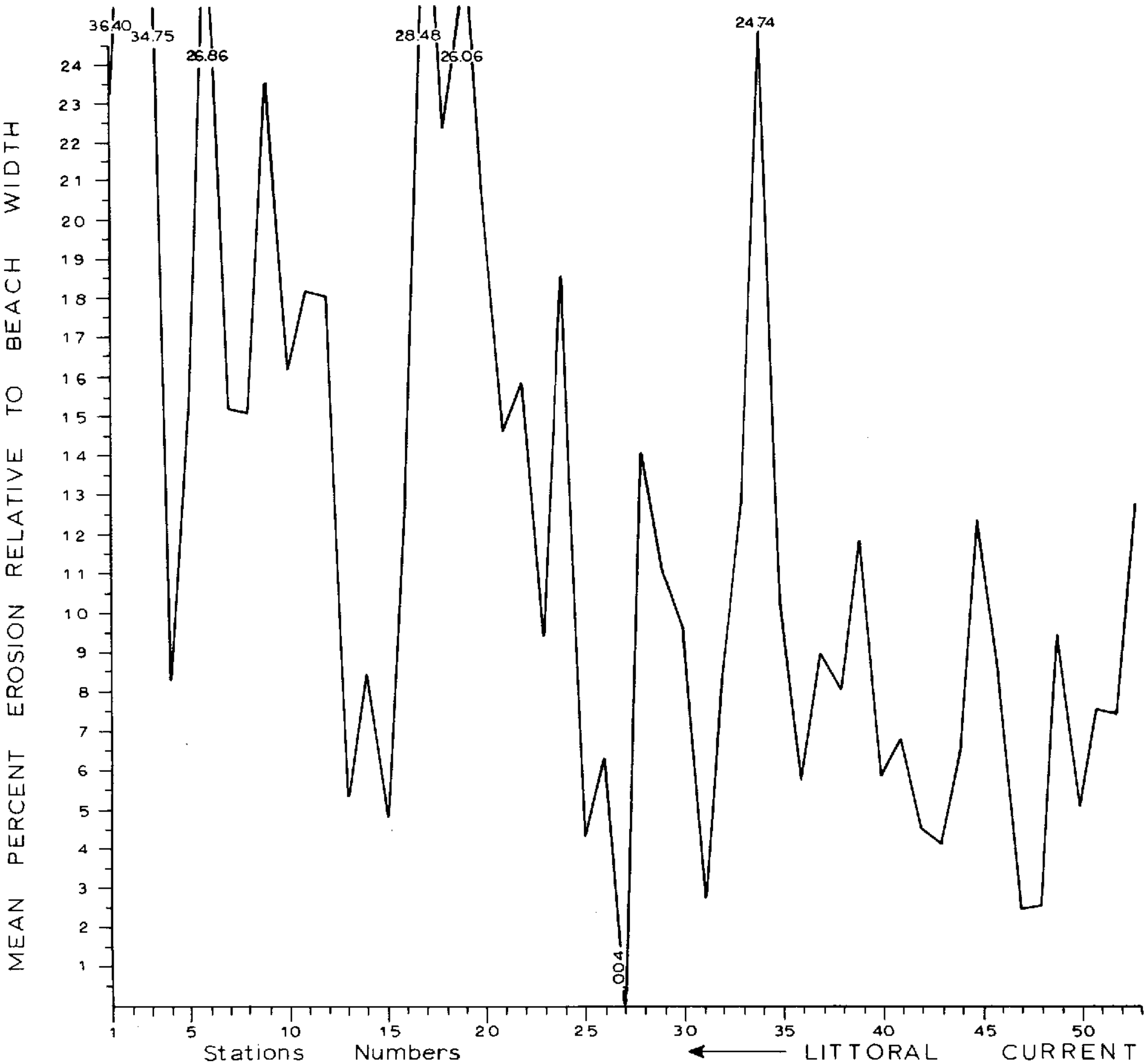

FIGURE 51

1939-1971 HIGH WATER LINE
ACCRETION INDEX NORTHERN TEST SECTION

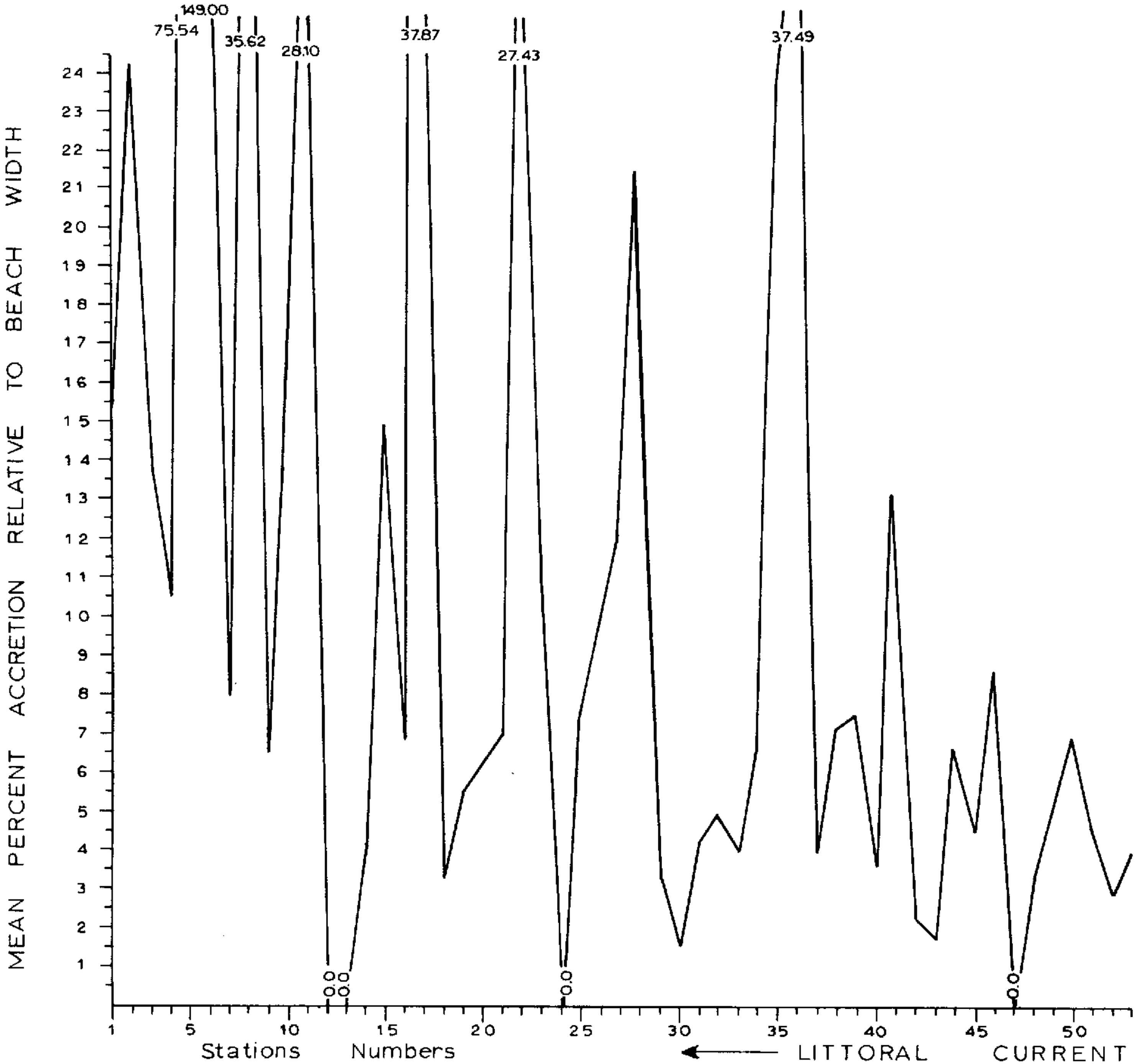

FIGURE 52

150

1939-1971 HIGH WATER LINE
EROSION INDEX SOUTHERN TEST SECTION

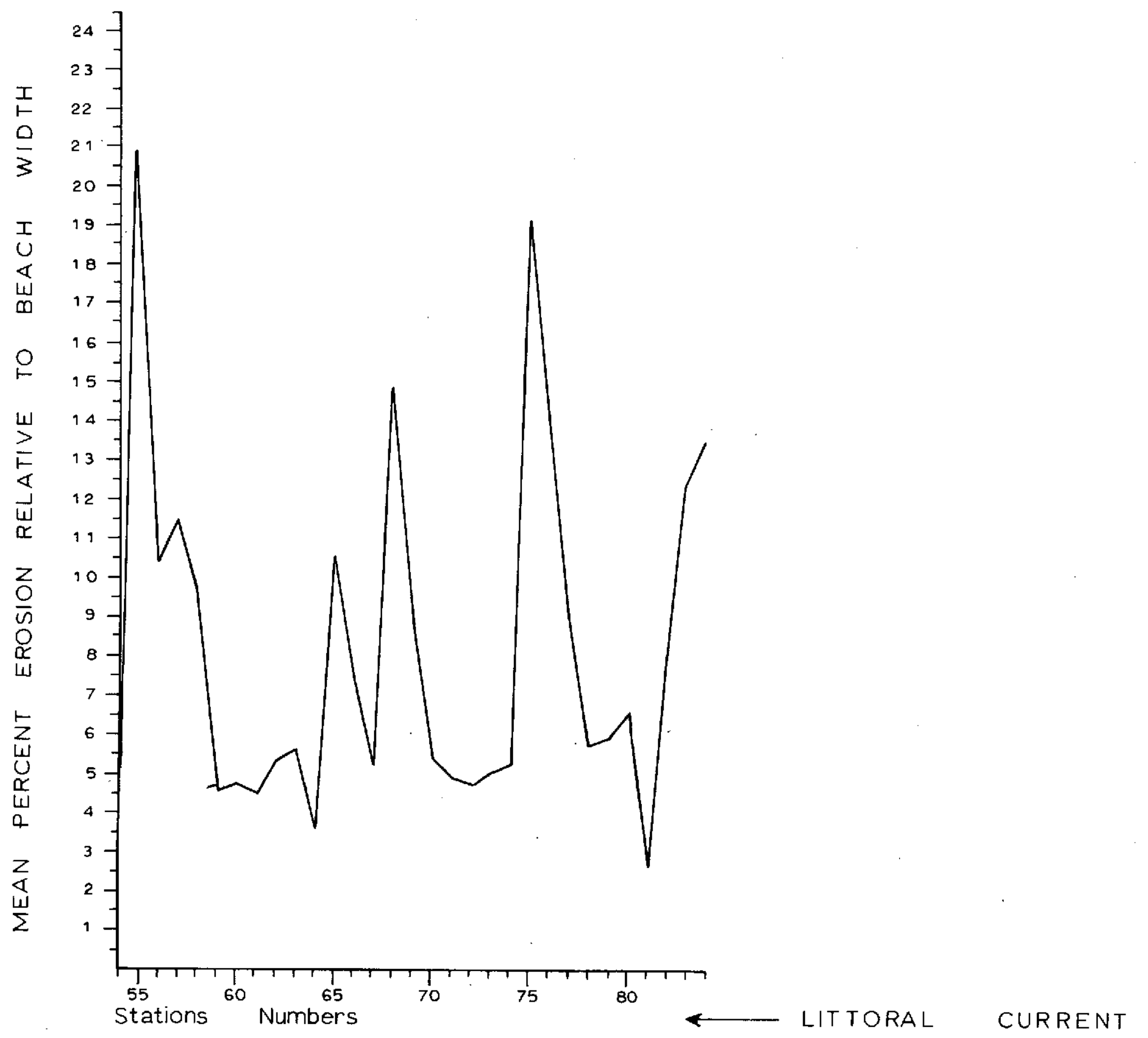

FIGURE 53

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1939-1971 HIGH WATER LINE
ACCRETION INDEX SOUTHERN TEST SECTION

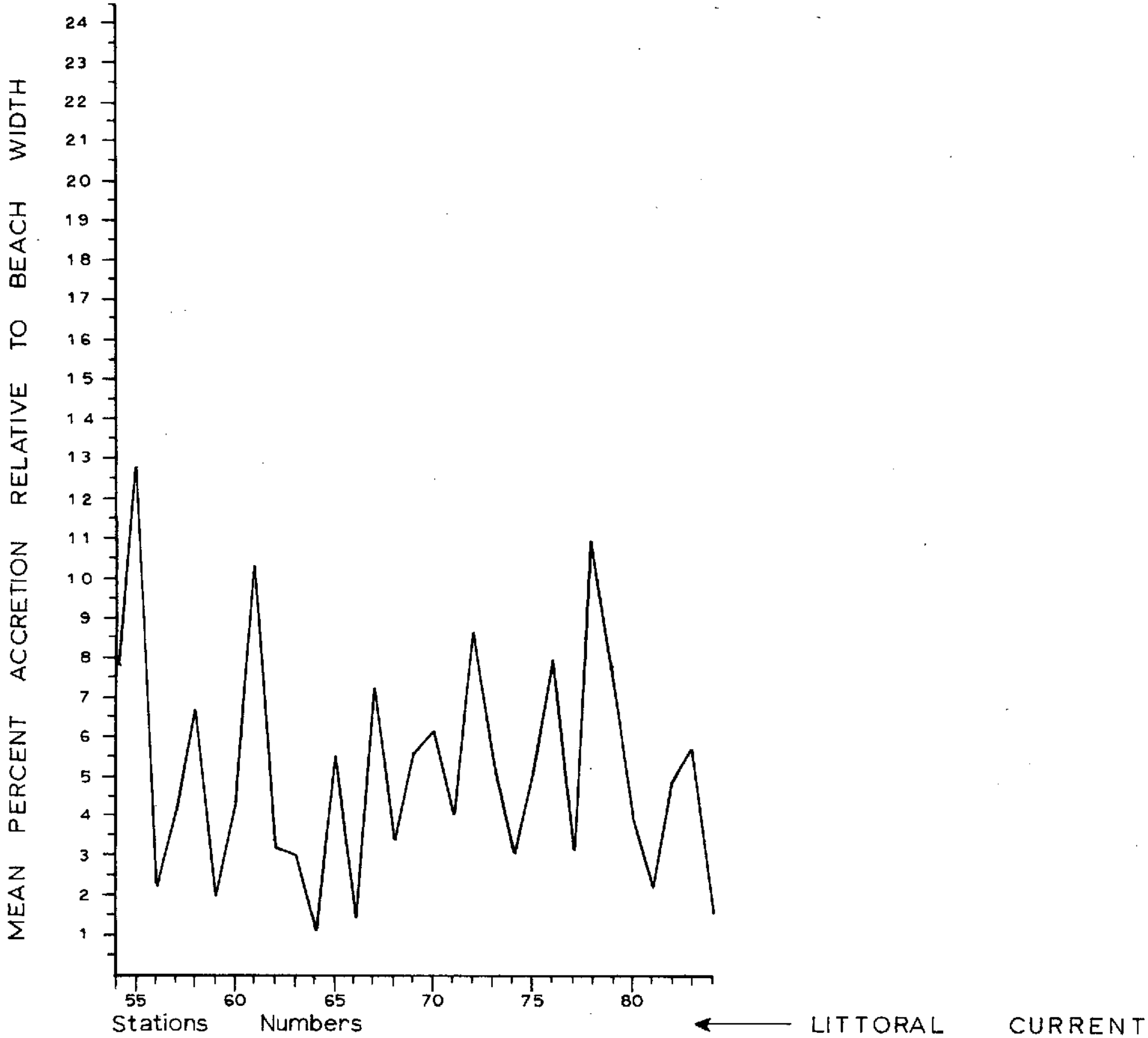

FIGURE 54

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and southern test sections (tabular data can be found in Appendix E). The indices were calculated for the high water line only because it is more responsive to changing wave conditions and sediment supply than the dune line, and a true dune line does not even exist throughout most of the northern test section.

The index was calculated by averaging the sum of the following operation: divide the rate of change during one time interval at one station by the beach width at that station in the beginning of the time interval:

$$I = \frac{1}{NUMINTS} \sum_{N=1}^{NUMINTS} \frac{RT_{K_{ij}}}{BW_{K_i}} \qquad (3)$$

NUMINTS = Number of time intervals
BW = Beach width
I = Change index

The indices were calculated for the following six time intervals: 1954-57, 1957-60, 1960-63, 1963-66, 1966-69, 1969-71. In most cases, the frequency of erosion and accretion should add up to six (Appendix F). However, if a beach width is zero, the ratio cannot be calculated because there can be no percent change in beach width. The frequencies, therefore, do not always add up to six. Another case in which frequencies do not add up to six is if there is no change in beach width, but this did not happen in either test section.[B3/]

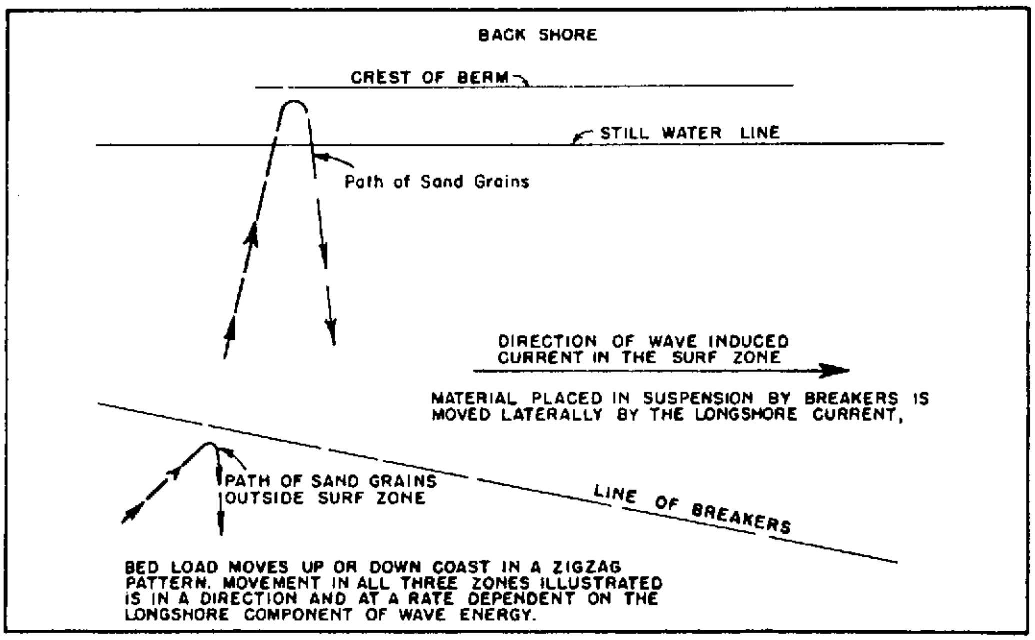
B3/ The change index says: only when erosion occurs at a given station, the beach width is decreased by a certain percent per year, and only when accretion occurs at a given station the beach width is increased by a certain percent per year. The frequency of occurrence is simply the number of times erosion or accretion occurred during the six time intervals.

APPENDIX C

COASTAL DYNAMIC PROCESSES

The energy sources that modify coasts are primarily wind and waves. The critical values of an incoming wave are its period, the direction from which the wave approaches, and its steepness (ratio of height to length). As waves approach shallow, nearshore water, their velocity and length decrease and their height increases. As waves break they release tremendous amounts of energy, and if waves break against a structure, they may be reflected and scour the foot of the structure; or they may set up shock pressures great enough to weaken or destroy the structure.

When waves break during their approach to a beach, they create, bottom currents roughly parallel to shore at the breaker line and just landward of the breakers. Another zone of sediment transport also initiated by incoming waves is in the swash zone. As waves rush up the beach slope and either deposit sand, transport sand down shore or both. Beach materials follow near parabolic paths in the swash zone. (Figure 1)



(Coastal Engineering Research Center, Technical Report 4)

To diagrammatically represent wave energy distribution and associated currents, orthogonals are drawn perpendicular to wave crests. Converging orthogonals indicate high energy concentration, whereas diverging orthogonals indicate energy disperson (Figure 2).

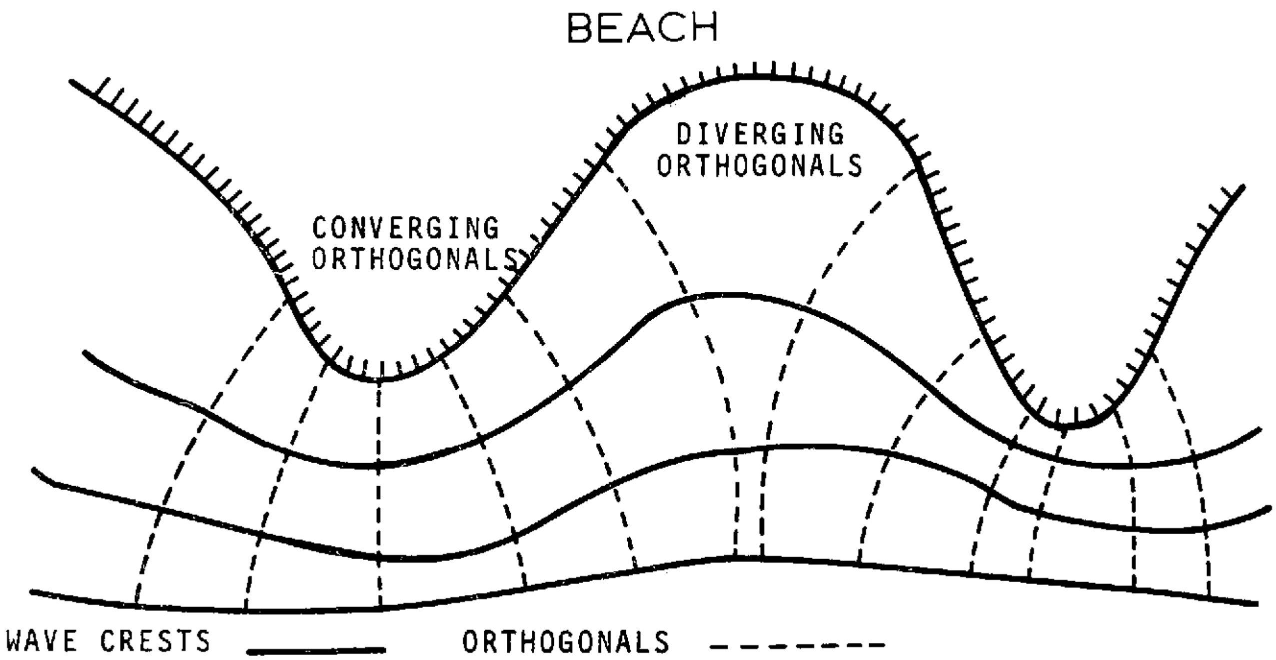


FIGURE 2

Wave diffraction occurs when energy is transmitted along the crest of an advancing wave that has been interrupted by a barrier such as a jetty or groin. The result is that waves are propagated in the lee of the barrier. The energy of these waves is less than the original wave, and is continually dispersing as indicated by diverging orthogonals (Figure 3).

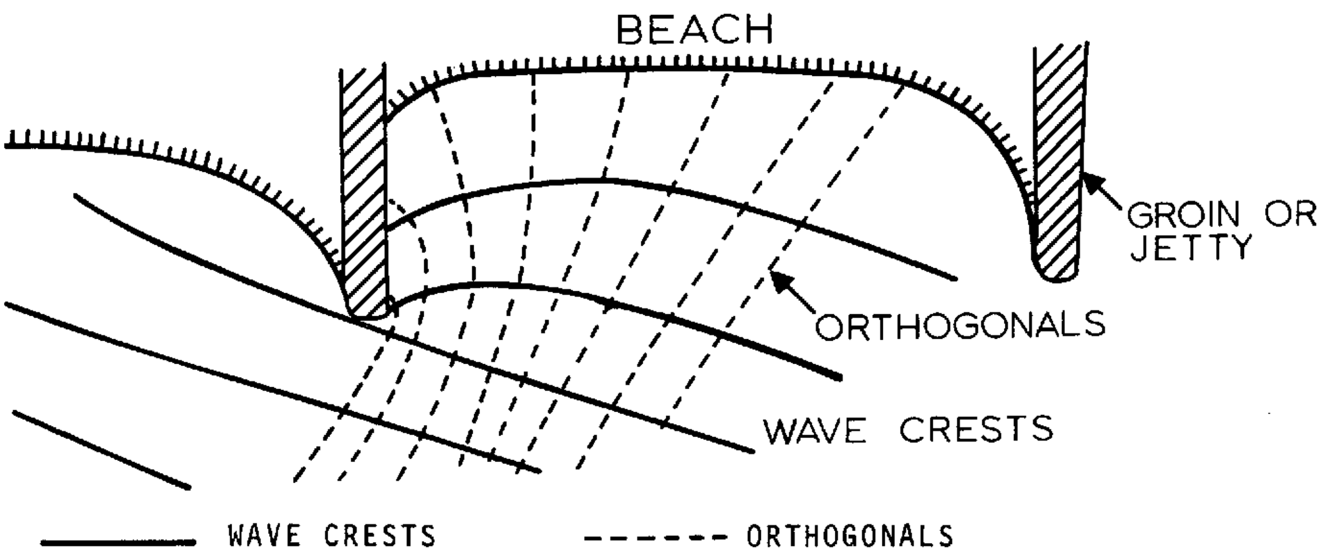


FIGURE 3

As these low energy waves impinge upon the shore, in the lee of a coastal structure only weak currents will be produced long shore, and the amount of sediment transported will be much less than for an interrupted wave.

Since the energy of a wave depends on the wave length and height, long low waves have less energy and can move less material in a given time than can very high steep waves.

Steep damaging waves are usually formed during storms, therefore waves conducive to beach accretion would be more likely to occur during a period of low storm frequency. Along the New Jersey Coast, this period generally exists during late spring, the entire summer and early fall, barring hurricane activity in late summer and early fall.

The process of sediment motion parallel to shore is a very normal continual process. There is a constant movement of material in dynamic equilibrium. If this flow is interrupted by natural or artificial barriers, large volumes of sand are impounded, denying a sediment source to areas downdrift of the barrier. The artificial barriers that appear along the New Jersey coast are primarily groins and jetties. Large volumes of sediment have been trapped at these structures, thereby reducing the amount of material available to nourish the beach farther downdrift.

APPENDIX E

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Mean and Standard Deviation
Of Rates of Shoreline Change
In Feet Per Year

HIGHLANDS BEACH TO MANASQUAN INLET

DUNE LINE

Year	All Rates of Change		Erosion Sites		Accretion Sites		Statistic
54-57	-2.08		5.33		5.38		$\bar{x}$
		7.88		7.58		5.43	s
57-60	1.85		7.57		6.20		$\bar{x}$
		1.35		14.20		7.01	s
60-63	3.25		9.16		6.49		$\bar{x}$
		13.61		12.44		9.27	s
63-66	1.24		4.57		3.45		$\bar{x}$
		6.64		6.49		3.07	s
66-69	-.05		2.26		3.59		$\bar{x}$
		3.83		2.04		3.17	s
69-71	-4.29		4.49		8.44		$\bar{x}$
		10.86		3.20		10.73	s
54-71	.28		2.54		1.24		$\bar{x}$
		2.62		2.50		1.23	s
60-61	2.48		17.45		14.27		$\bar{x}$
		25.73		25.11		13.09	s
61-62	14.78		58.41		35.29		$\bar{x}$
		77.64		72.87		43.76	s
62-63	2.69		23.11		14.10		$\bar{x}$
		33.20		30.53		24.45	s
Statistic	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	

Mean and Standard Deviation
Of Rates of Shoreline Change
In Feet Per Year

HIGHLANDS BEACH TO MANASQUAN INLET

HIGH WATER LINE

Year	All Rates of Change		Erosion Sites		Accretion Sites		Statistic
54-57	-4.84		7.12		9.69		$\bar{X}$
		10.16		6.72		6.71	s
57-60	-0.86		13.41		14.61		$\bar{X}$
		21.17		15.95		15.85	s
60-63	-2.57		7.22		10.09		$\bar{X}$
		11.86		5.15		9.88	s
63-66	3.22		8.95		6.23		$\bar{X}$
		10.48		8.09		6.24	s
66-69	-1.97		4.13		6.65		$\bar{X}$
		7.12		4.84		4.57	s
69-71	29.71		31.01		3.43		$\bar{X}$
		17.82		16.87		0.24	s
54-71	1.15		2.70		1.78		$\bar{X}$
		2.87		2.14		1.40	s
60-61	17.67		29.72		12.85		$\bar{X}$
		27.56		22.39		10.17	s
61-62	16.58		45.07		20.96		$\bar{X}$
		48.24		41.30		16.48	s
62-63	-24.24		14.72		32.34		$\bar{X}$
		35.62		12.24		33.16	s
Statistic	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	

Mean and Standard Deviation
Of Rates of Shoreline Change
In Feet Per Year

ISLAND BEACH STATE PARK

DUNE LINE

Year	All Rates of Change		Erosion Sites		Accretion Sites		Statistic
54-57	2.16		3.42		5.15		$\bar{X}$
		5.23		2.91		3.64	s
57-60	6.15		8.26		4.77		$\bar{X}$
		8.28		7.07		4.90	s
60-63	15.14		17.38		5.80		$\bar{X}$
		12.70		11.01		7.35	s
63-66	.08		6.32		8.55		$\bar{X}$
		10.66		6.35		9.38	s
66-69	-9.22		3.58		12.96		$\bar{X}$
		12.70		2.56		12.01	s
69-71	7.01		15.19		10.15		$\bar{X}$
		17.41		14.03		9.47	s
54-71	2.17		3.65		1.30		$\bar{X}$
		3.07		2.37		.84	s
60-61	-20.71		9.51		33.07		$\bar{X}$
		29.49		6.62		25.96	s
61-62	140.51		190.63		27.79		$\bar{X}$
		114.83		118.80		15.34	s
62-63	3.38		19.57		30.67		$\bar{X}$
		32.22		16.36		41.03	s
Statistic	$\bar{X}$	s	$\bar{X}$	s	$\bar{X}$	s	

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Mean and Standard Deviation
Of Rates of Shoreline Change
In Feet Per Year

ISLAND BEACH STATE PARK

HIGH WATER LINE

Year	All Rates of Change		Erosion Sites		Accretion Sites		Statistic
54-57	-3.12		5.51		8.73		$\bar{X}$
		8.97		5.30		5.48	s
57-60	-1.15		9.67		7.99		$\bar{X}$
		10.28		4.79		5.89	s
60-63	3.11		11.44		10.08		$\bar{X}$
		12.48		6.94		5.99	s
63-66	1.00		17.20		12.33		$\bar{X}$
		19.31		15.71		8.95	s
66-69	-5.00		4.87		8.44		$\bar{X}$
		8.74		4.55		7.05	s
69-71	31.02		34.58		2.14		$\bar{X}$
		18.90		16.18		.94	s
54-71	1.38		3.09		1.31		$\bar{X}$
		3.05		3.18		1.16	s
60-61	52.30		52.30		---		$\bar{X}$
		25.48		25.48		---	s
61-62	-14.68		53.55		40.38		$\bar{X}$
		47.88		50.35		27.42	s
62-63	-14.77		29.06		51.09		$\bar{X}$
		44.54		15.37		39.00	s
Statistic	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	

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APPENDIX F

EROSION INDICES
HIGHLANDS BEACH TO MANASQUAN INLET

STATION	MEAN PERCENT EROSION INDEX	FREQUENCY OF OCCURRENCE	STATION	MEAN PERCENT EROSION INDEX	FREQUENCY OF OCCURRENCE
1	23.44*	3	28	14.19*	3
2	36.40*	3	29	11.07	3
3	34.75*	3	30	9.60	3
4	8.32	4	31	2.74	3
5	15.19*	3	32	8.24	1
6	26.86*	3	33	12.73*	3
7	15.24	2	34	24.74	2
8	15.15*	5	35	10.20	3
9	23.52	1	36	5.77	4
10	16.16*	4	37	8.90	3
11	18.17*	4	38	8.07	3
12	18.11*	4	39	11.84	2
13	5.38	6	40	5.81	3
14	8.43	4	41	6.78	4
15	4.75	3	42	4.58	5
16	12.61	3	43	4.19	5
17	28.48*	3	44	6.62	4
18	22.33	2	45	12.31	2
19	26.09	2	46	8.47	3
20	21.03	2	47	2.49	7
21	14.63	2	48	2.55	1
22	15.85*	4	49	9.44	3
23	9.41	4	50	5.11	4
24	18.54*	4	51	7.54	3
25	4.35	4	52	7.46	2
26	6.39	4	53	12.74	2
27	.47	1			

MEAN EROSION INDEX 12.72% STANDARD DEVIATION 8.32

166

MEAN FREQUENCY OF OCCURRENCE 3.15

*High frequency, high severity

ACCRETION INDICES
HIGHLANDS BEACH TO MANASQUAN INLET

STATION	MEAN PERCENT ACCRETION INDEX	FREQUENCY OF OCCURRENCE	STATION	MEAN PERCENT ACCRETION INDEX	FREQUENCY OF OCCURRENCE
1	-15.04*	3	28	-21.34*	3
2	-24.20	2	29	-3.76	3
3	-13.97*	3	30	-1.55	3
4	-10.48	2	31	-4.02	3
5	-75.54*	3	32	-4.88	5
6	-149.00*	3	33	-3.97	3
7	-7.84	4	34	-6.53	4
8	-35.62	1	35	-23.47*	3
9	-6.43	1	36	-37.49	2
10	-16.13	2	37	-3.79	3
11	-28.10	2	38	-7.05	3
12	0.0	0	39	-7.45	4
13	0.0	0	40	-3.57	3
14	-3.88	2	41	-13.06	2
15	-14.83*	3	42	-2.24	1
16	-6.72	3	43	-1.65	1
17	-37.87*	3	44	-6.52	2
18	-3.36	4	45	-4.45	4
19	-5.60	4	46	-8.54	3
20	-6.18	4	47	0.0	0
21	-7.04	4	48	-3.26	5
22	-27.43	2	49	-4.97	3
23	-11.52	2	50	-6.85	2
24	0.0	0	51	-4.48	3
25	-7.47	2	52	-2.81	4
26	-9.62	2	53	-3.84	4
27	-12.36	1			

MEAN ACCRETION INDEX 13.73% STANDARD DEVIATION 2.3
MEAN FREQUENCY OF OCCURRENCE 2.66

147

*High frequency, high severity

EROSION INDICES
ISLAND BEACH STATE PARK

STATION	MEAN PERCENT EROSION INDEX	FREQUENCY OF OCCURRENCE	STATION	MEAN PERCENT EROSION INDEX	FREQUENCY OF OCCURRENCE
54	5.16	4	79	5.95	4
55	20.96	2	80	6.64	3
56	10.46	2	81	2.67	4
57	11.50	2	82	7.90	4
58	9.75*	3	83	12.46*	4
59	4.64	2	84	13.53*	3
60	4.76	3			
61	4.56	3			
62	5.39	3			
63	5.62	2			
64	3.64	2			
65	10.64	2			
66	7.34	3			
67	5.27	3			
68	14.87	2			
69	8.82*	3			
70	5.43	4			
71	4.84	3			
72	4.70	4			
73	5.01	4			
74	5.32	3			
75	19.17	2			
76	14.24*	3			
77	9.00*	3			
78	5.71	4			

MEAN EROSION INDEX 8.25% STANDARD DEVIATION 4.5
MEAN FREQUENCY OF OCCURRENCE 3.00

11a 8

*High frequency, high severity

ACCRETION INDICES
ISLAND BEACH STATE PARK

STATION	MEAN PERCENT ACCRETION INDEX	FREQUENCY OF OCCURRENCE	STATION	MEAN PERCENT ACCRETION INDEX	FREQUENCY OF OCCURRENCE
54	-7.83	2	79	-7.74	2
55	-12.81*	4	80	-3.91	3
56	-2.20	4	81	-2.15	2
57	-4.25	4	82	-4.85	2
58	-6.76*	3	83	-5.64	2
59	-2.02	4	84	-1.48	3
60	-4.29	3			
61	-10.27*	3			
62	-3.17	3			
63	-3.00	4			
64	-1.14	4			
65	-5.48*	4			
66	-1.45	3			
67	-7.23*	3			
68	-3.44	4			
69	-5.58*	3			
70	-6.06	2			
71	-4.02	3			
72	-8.57	2			
73	-5.21	2			
74	-3.03	3			
75	-5.08	4			
76	-7.91*	3			
77	-3.13	3			
78	-10.92	2			

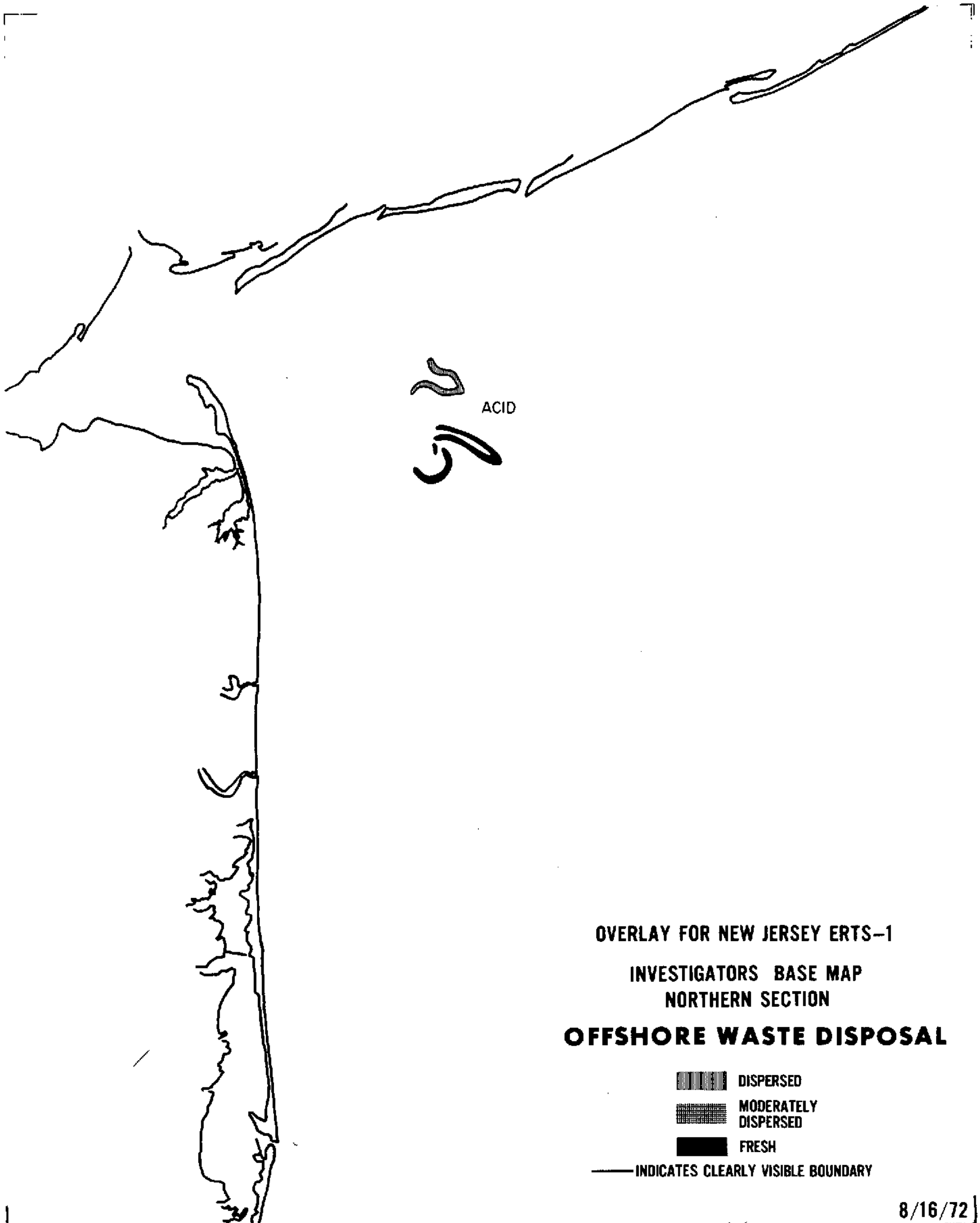
MEAN ACCRETION INDEX 5.18% STANDARD DEVIATION 2.9

169

MEAN FREQUENCY OF OCCURRENCE 3.00

*High frequency, high severity

APPENDIX G



OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

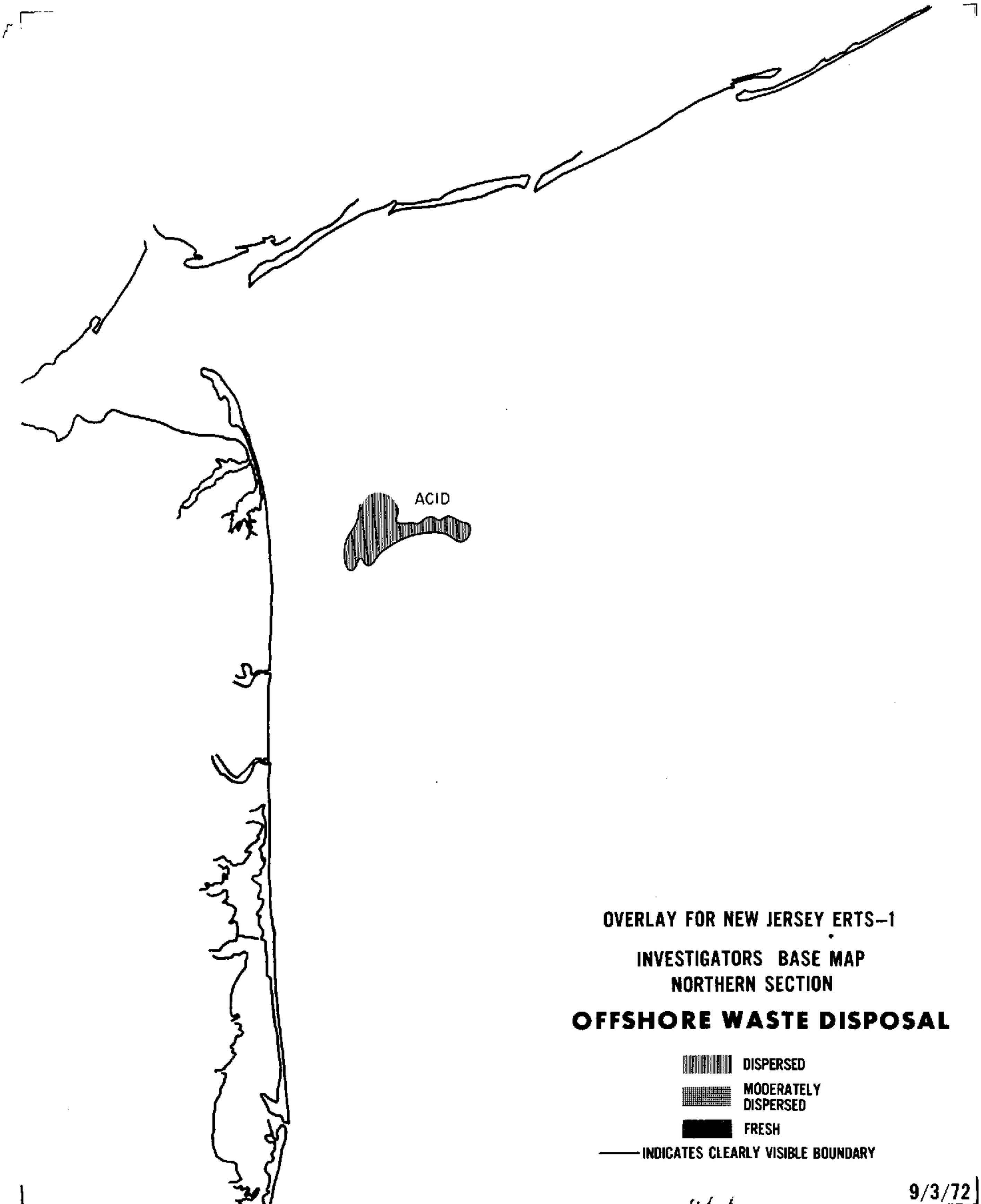
DISPERSED

MODERATELY DISPERSED

FRESH

——INDICATES CLEARLY VISIBLE BOUNDARY

8/16/72



OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

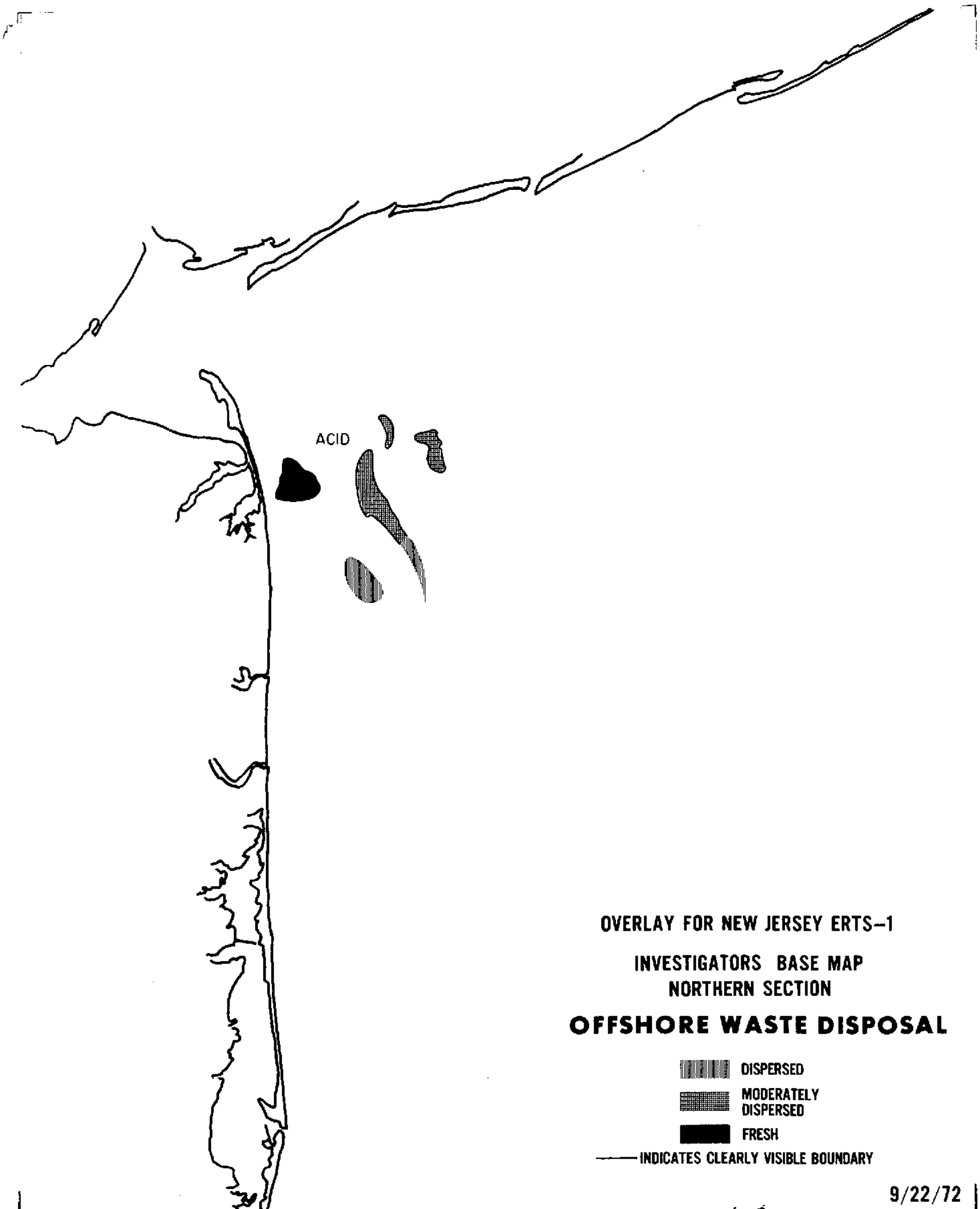
DISPERSED

MODERATELY DISPERSED

FRESH

—— INDICATES CLEARLY VISIBLE BOUNDARY

9/3/72



OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

DISPERSED

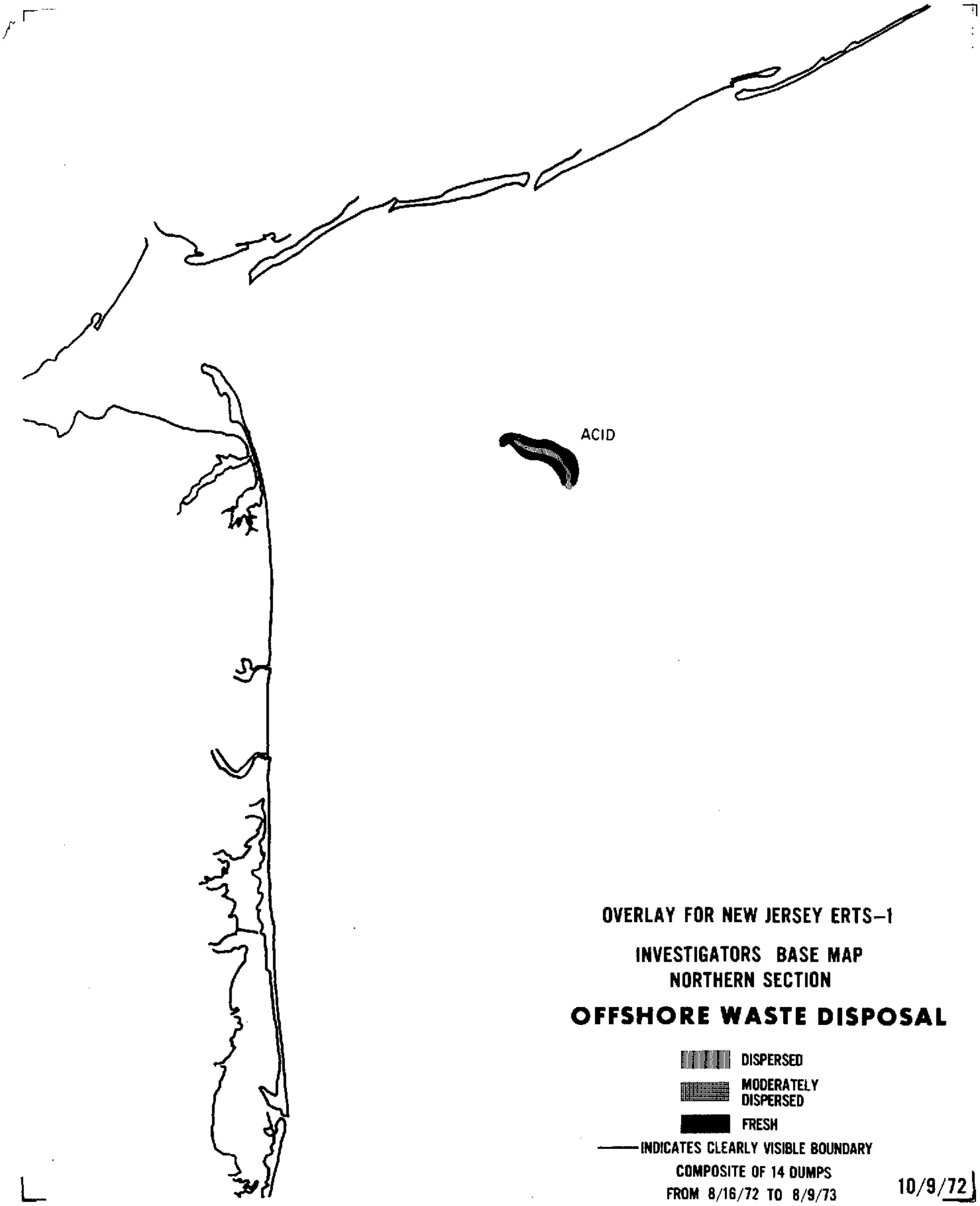
MODERATELY DISPERSED

FRESH

—— INDICATES CLEARLY VISIBLE BOUNDARY

9/22/72

173



OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

DISPERSED

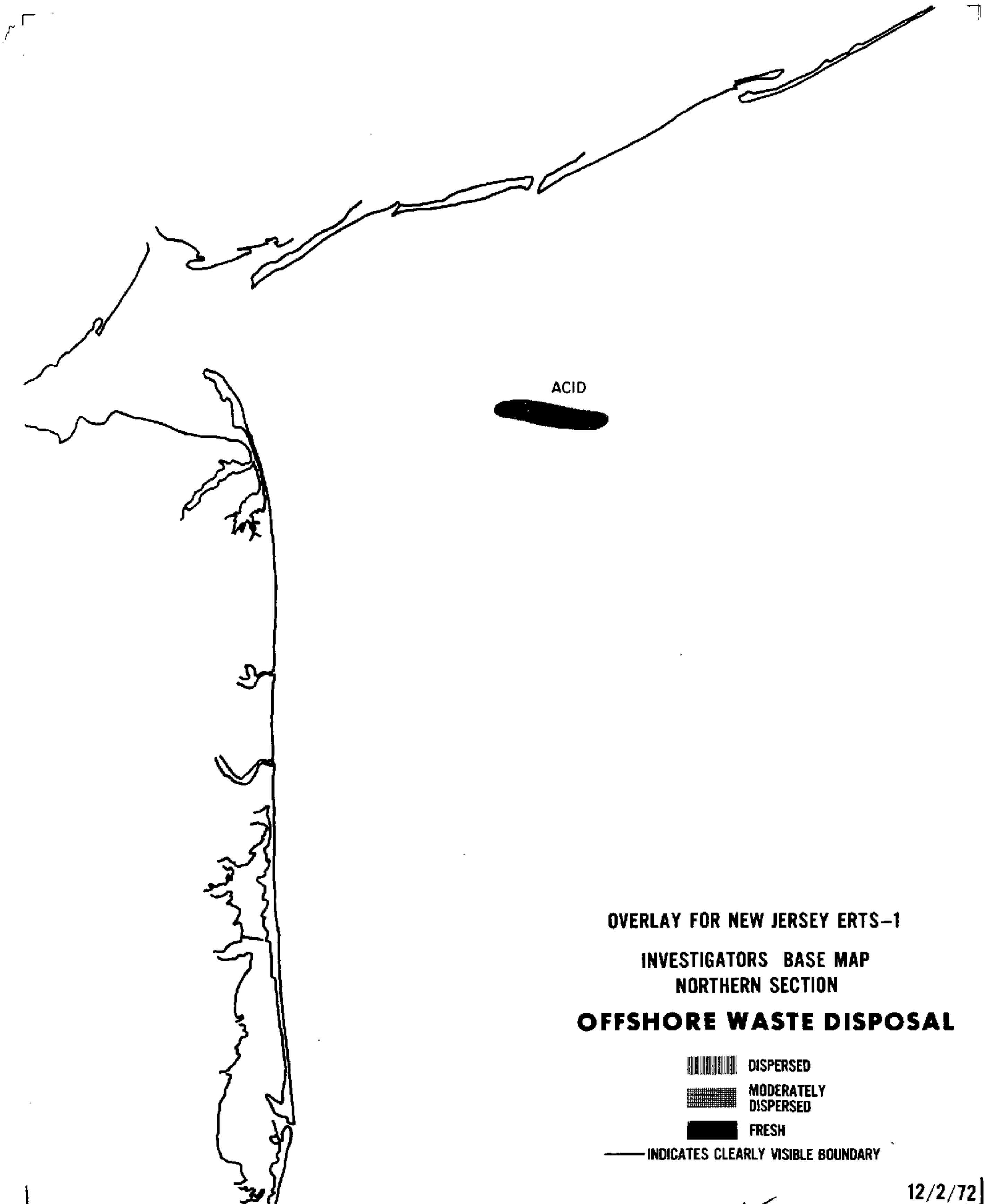
MODERATELY DISPERSED

FRESH

—— INDICATES CLEARLY VISIBLE BOUNDARY

COMPOSITE OF 14 DUMPS
FROM 8/16/72 TO 8/9/73

10/9/72

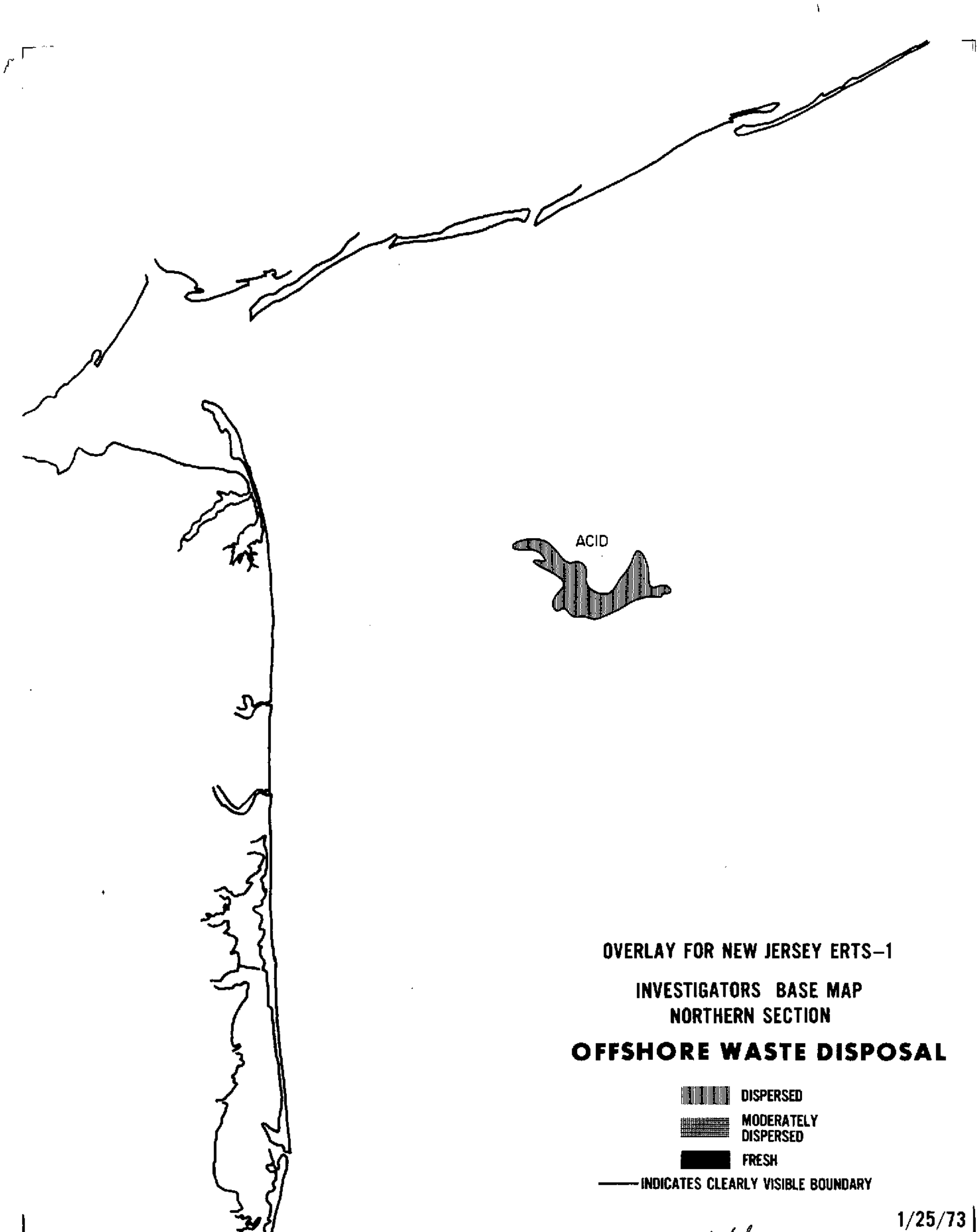


OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

12/2/72



OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

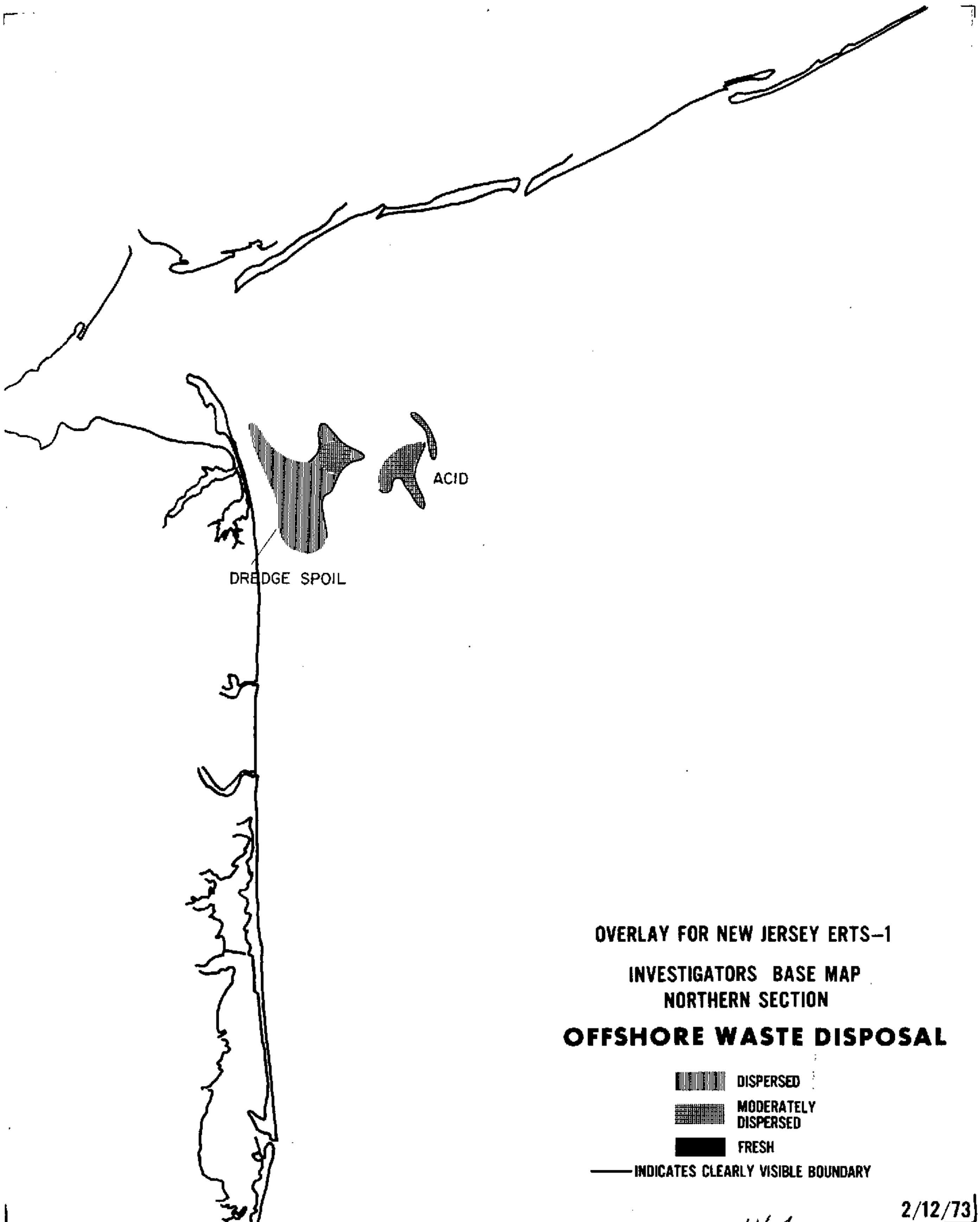
DISPERSED

MODERATELY DISPERSED

FRESH

——INDICATES CLEARLY VISIBLE BOUNDARY

1/25/73



OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

DISPERSED

MODERATELY DISPERSED

FRESH

——INDICATES CLEARLY VISIBLE BOUNDARY

2/12/73

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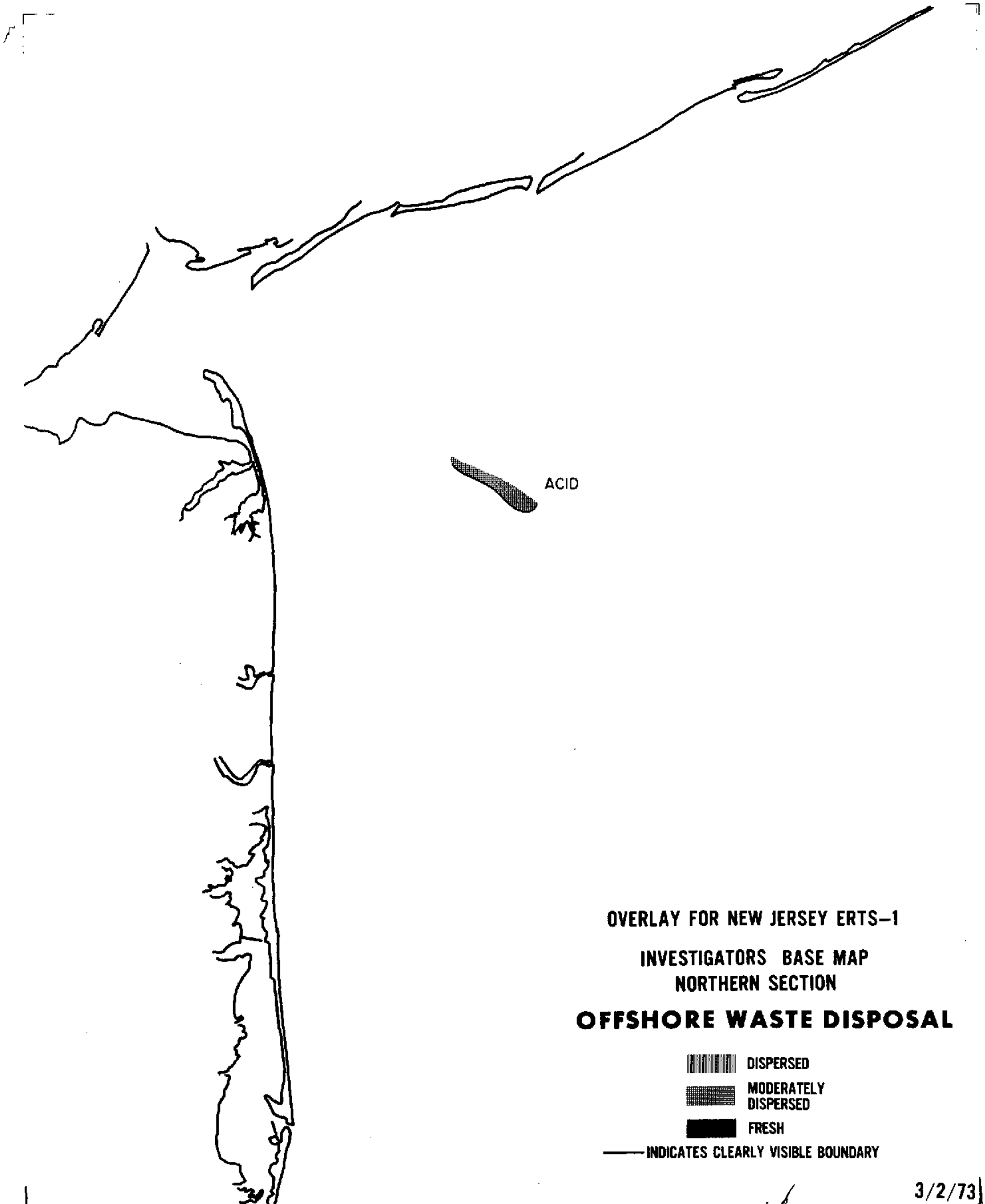


OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

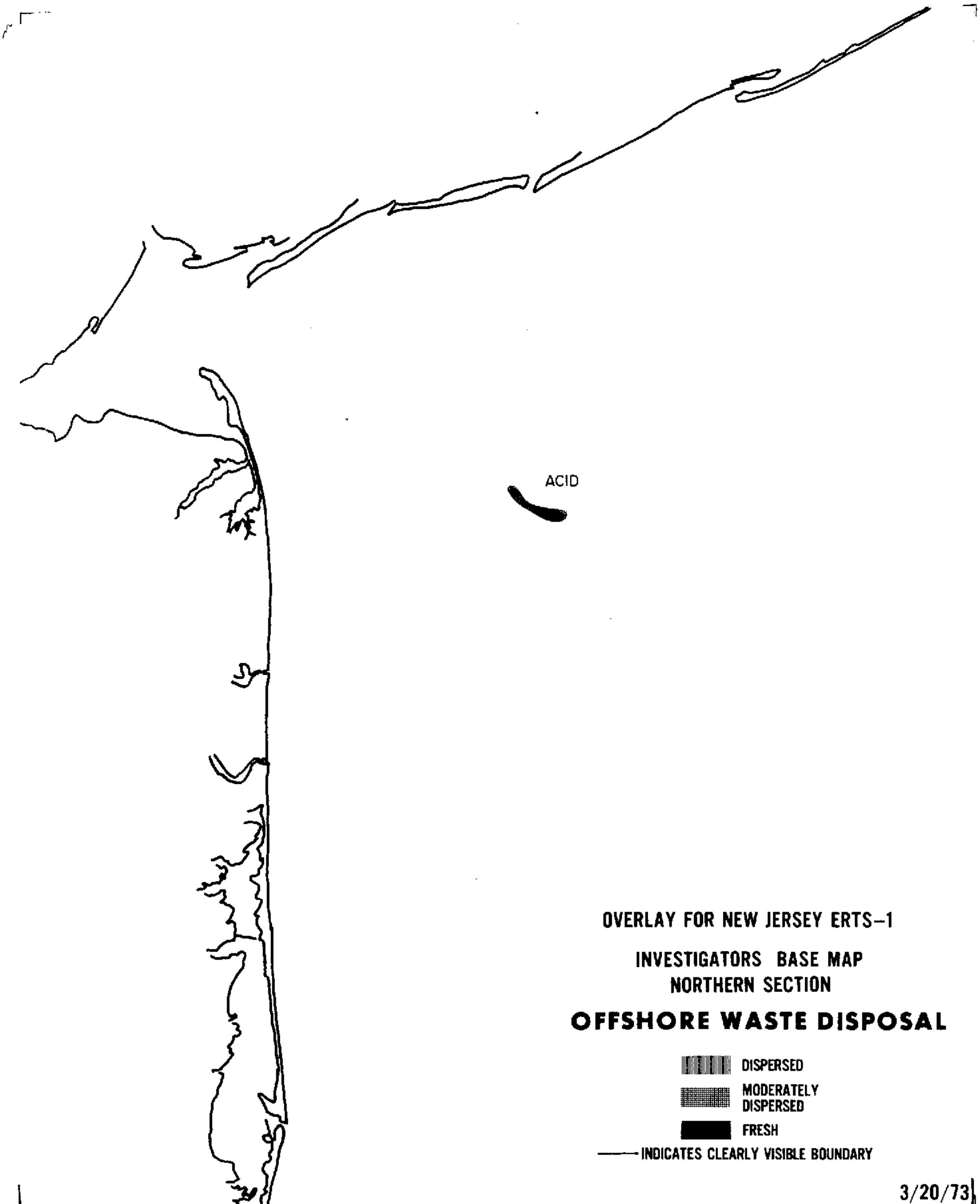
DISPERSED

MODERATELY DISPERSED

FRESH

——INDICATES CLEARLY VISIBLE BOUNDARY

3/2/73



OVERLAY FOR NEW JERSEY ERTS-1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

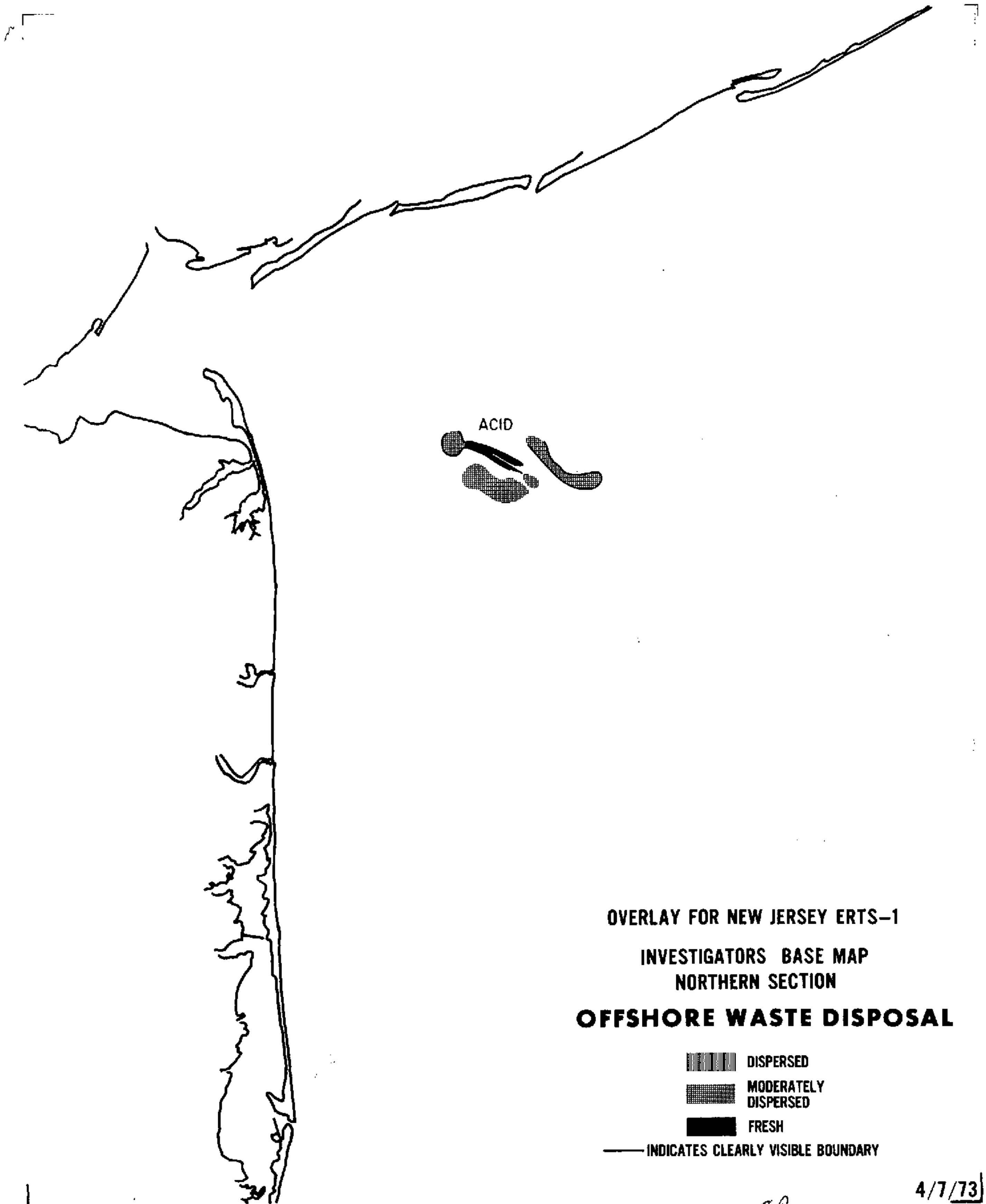
DISPERSED

MODERATELY DISPERSED

FRESH

—— INDICATES CLEARLY VISIBLE BOUNDARY

3/20/73



OVERLAY FOR NEW JERSEY ERTS–1

INVESTIGATORS BASE MAP
NORTHERN SECTION

OFFSHORE WASTE DISPOSAL

4/7/73

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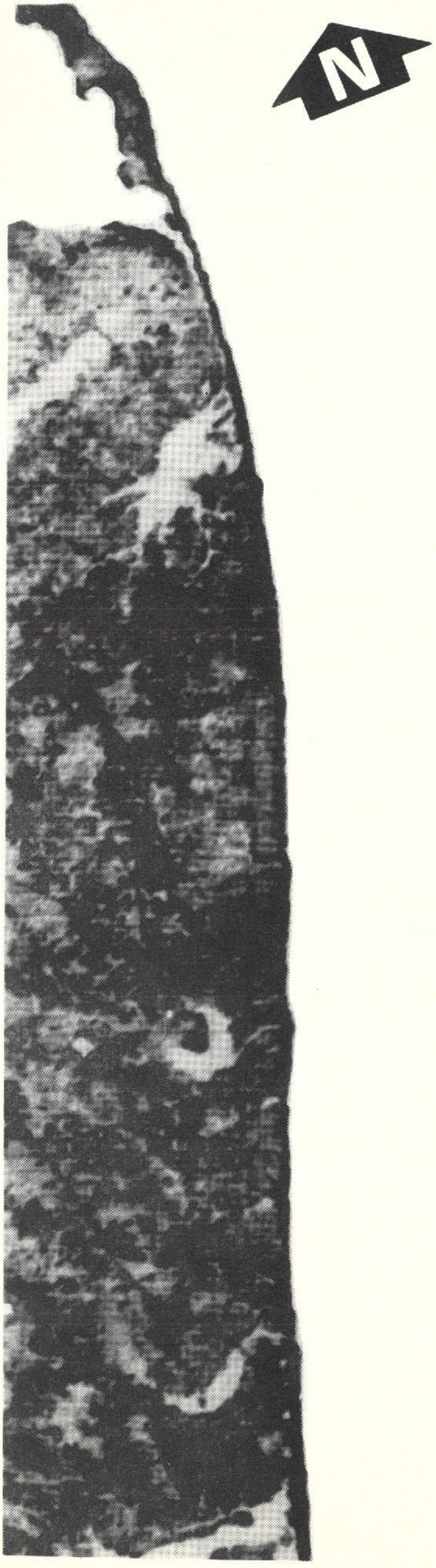
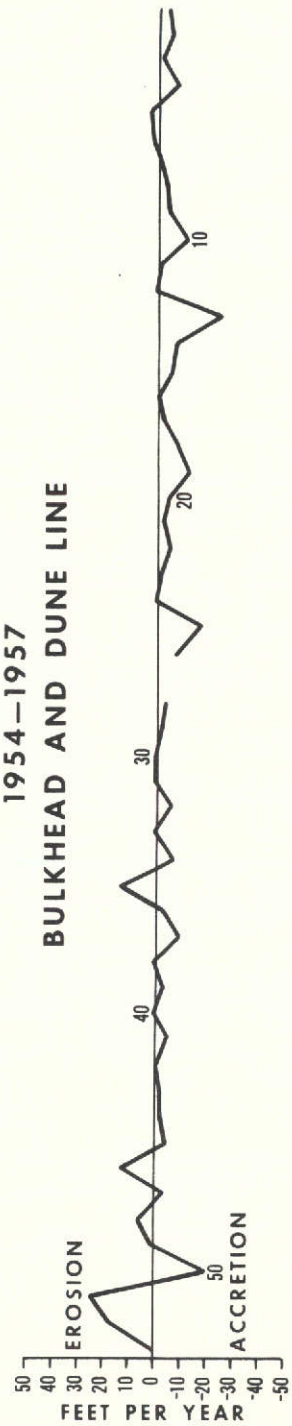
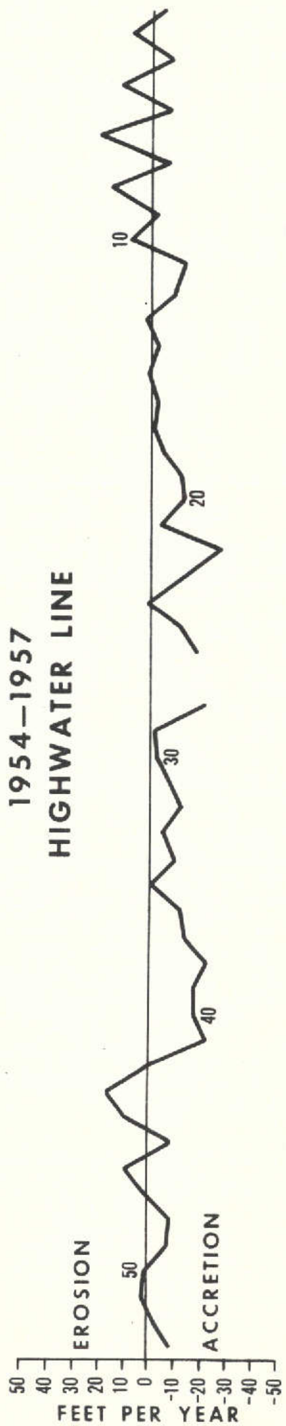
APPENDIX D







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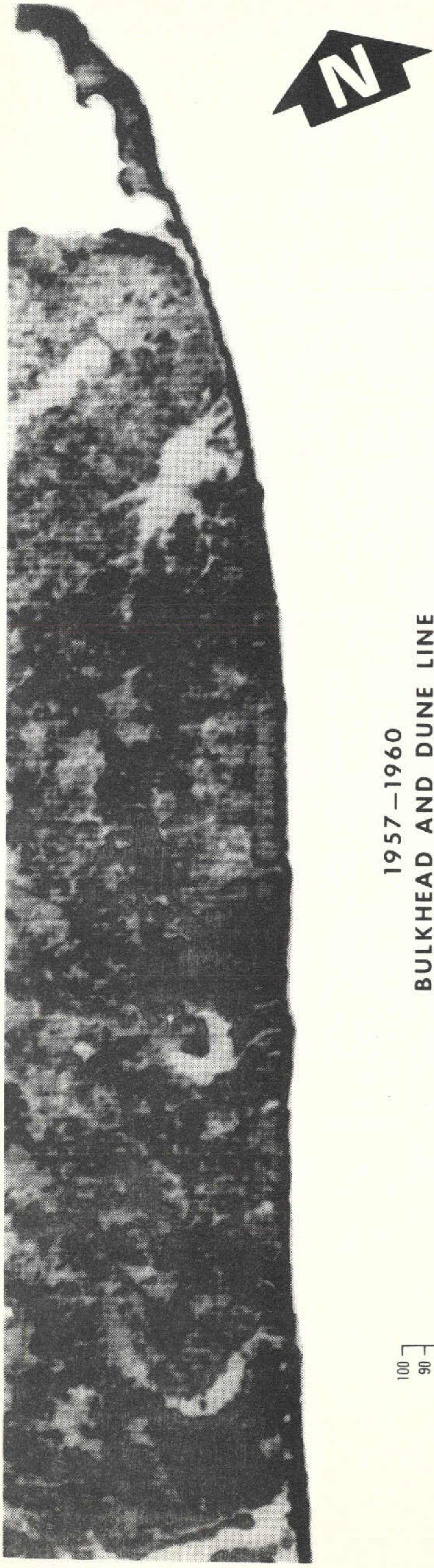
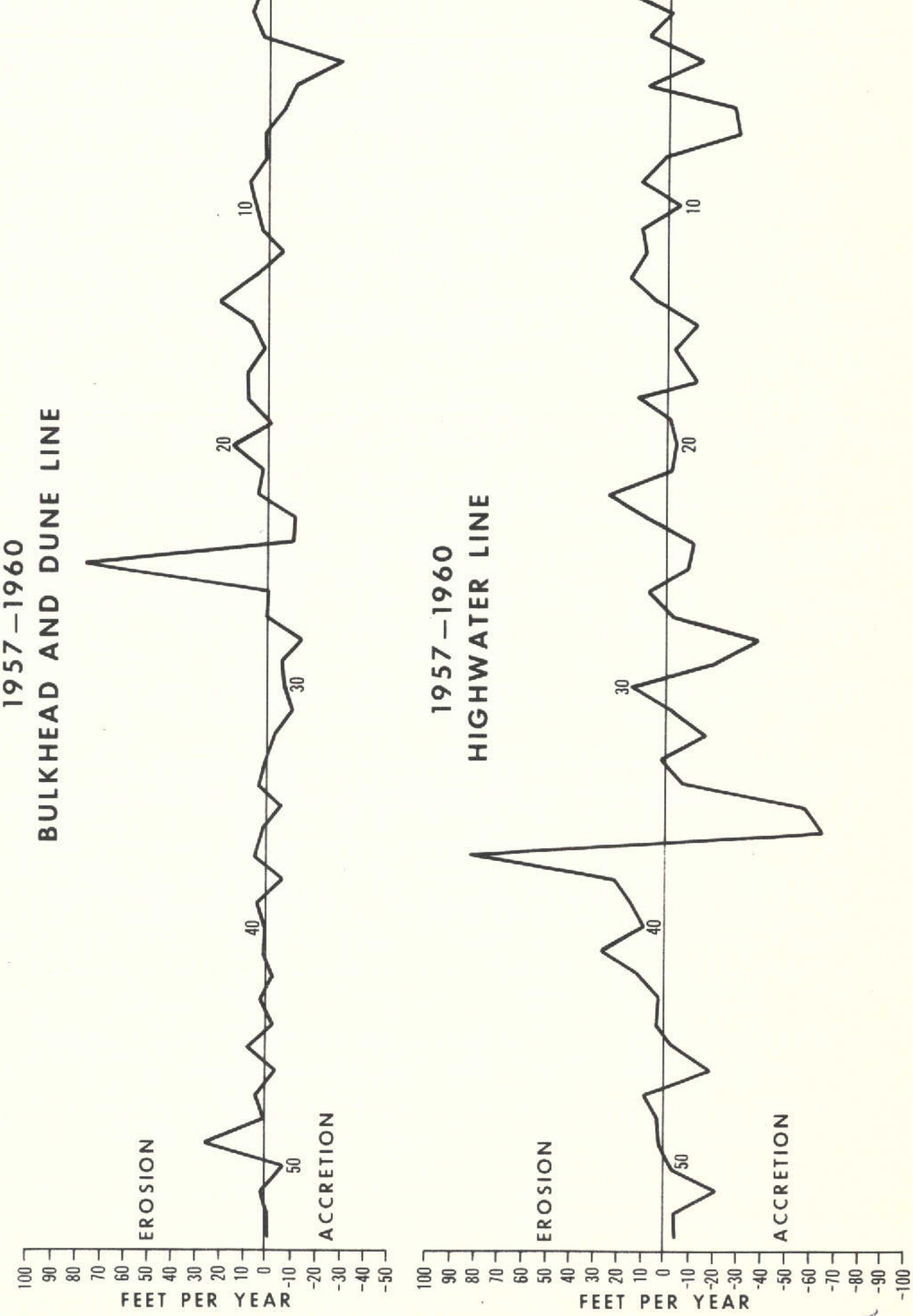
EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006





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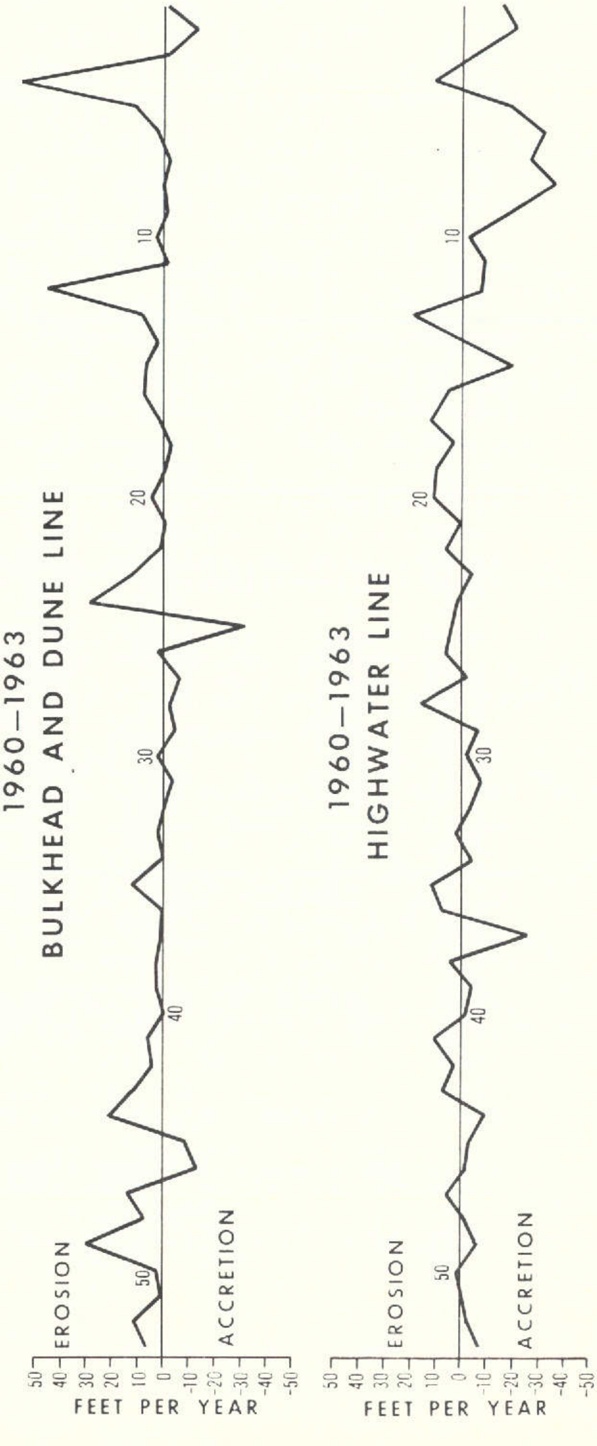

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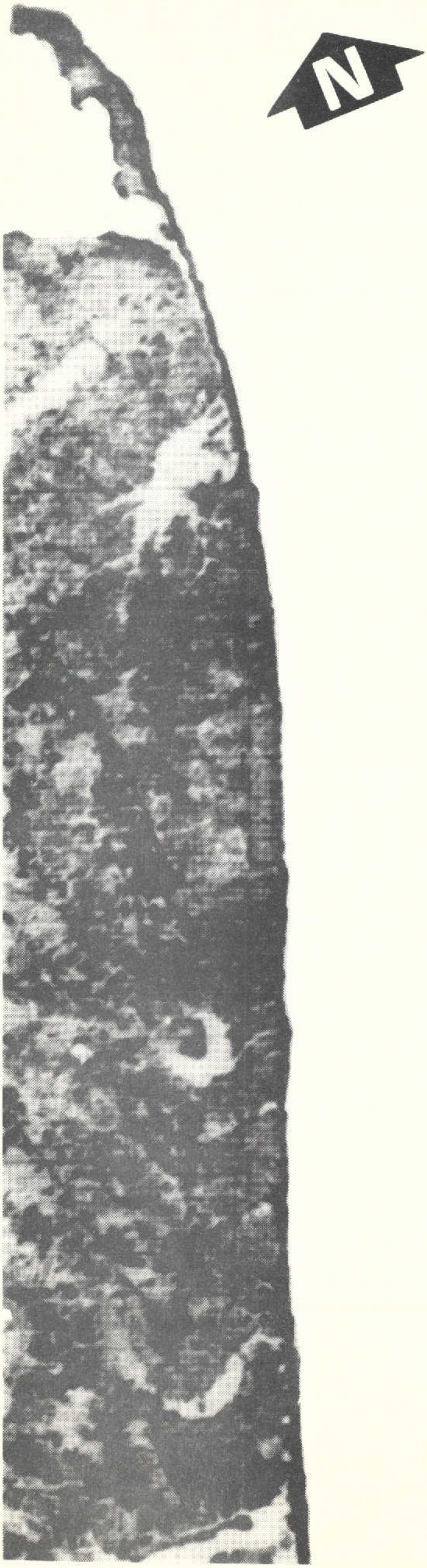

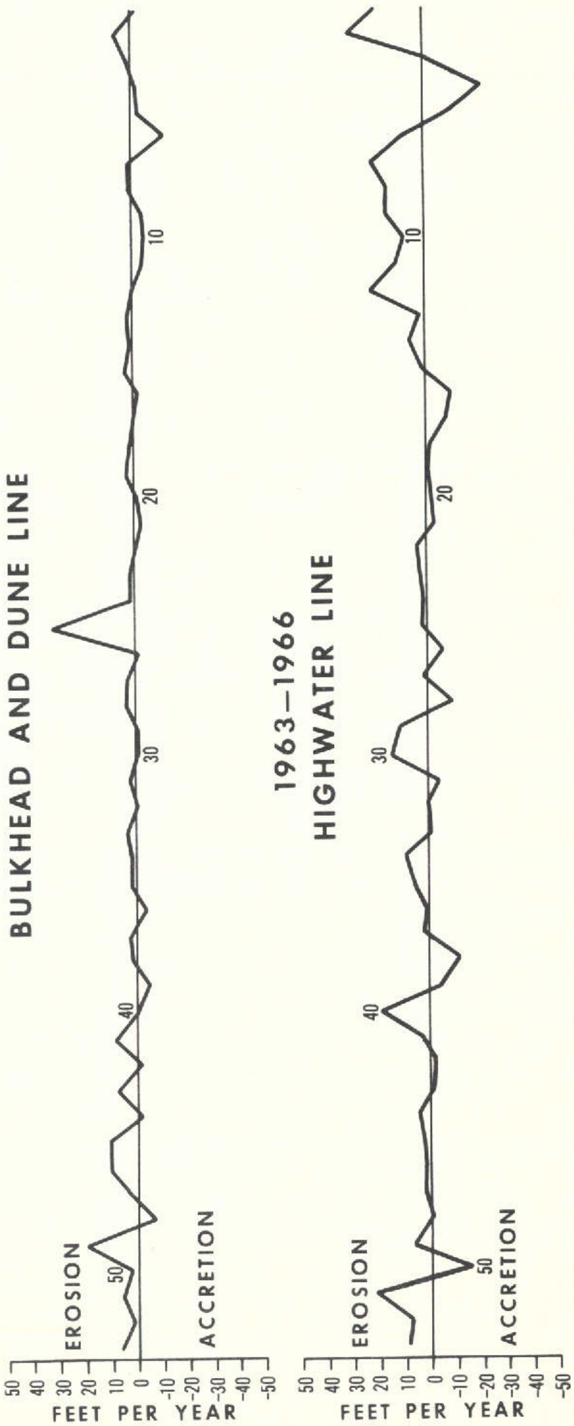

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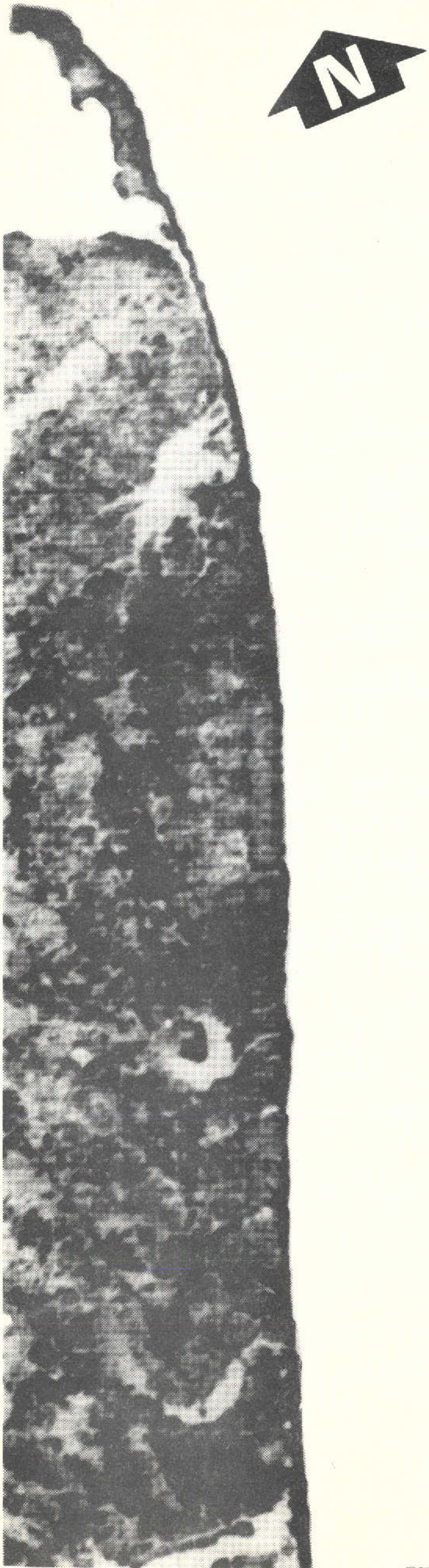

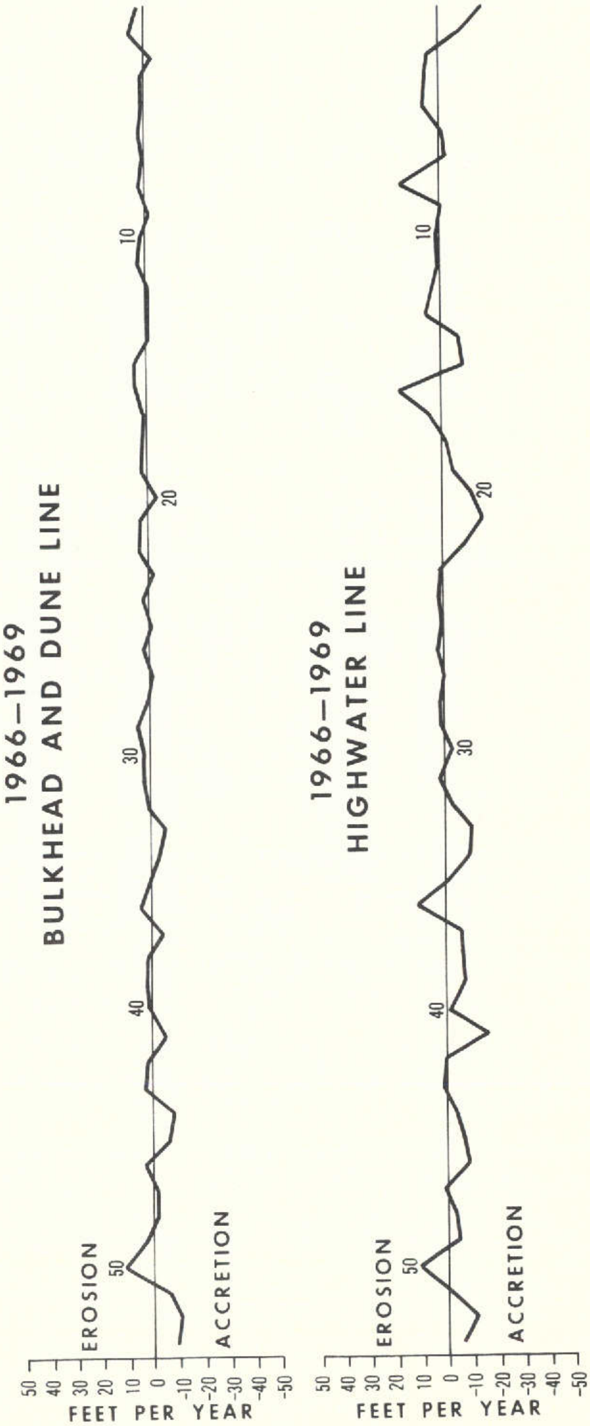

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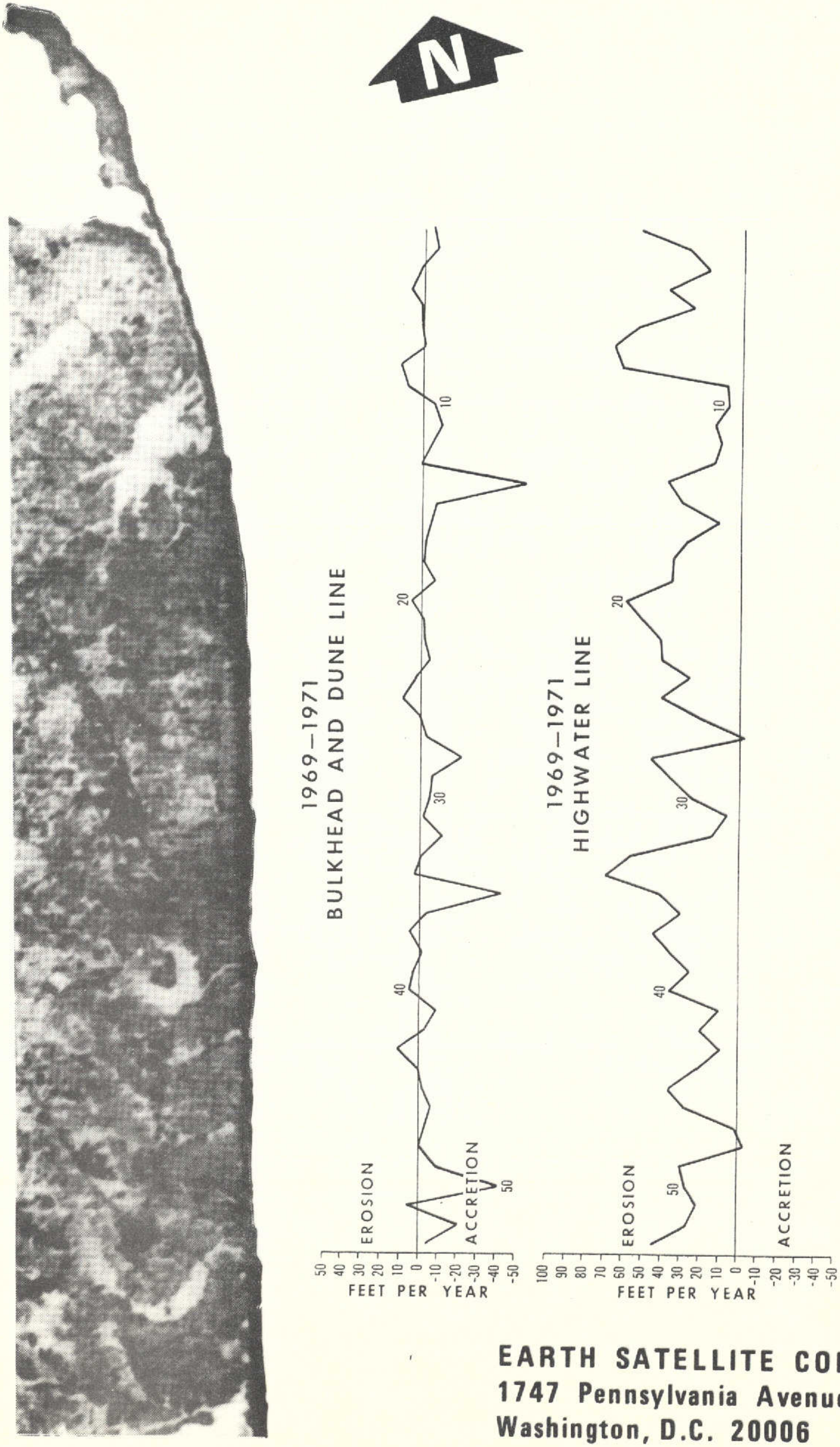

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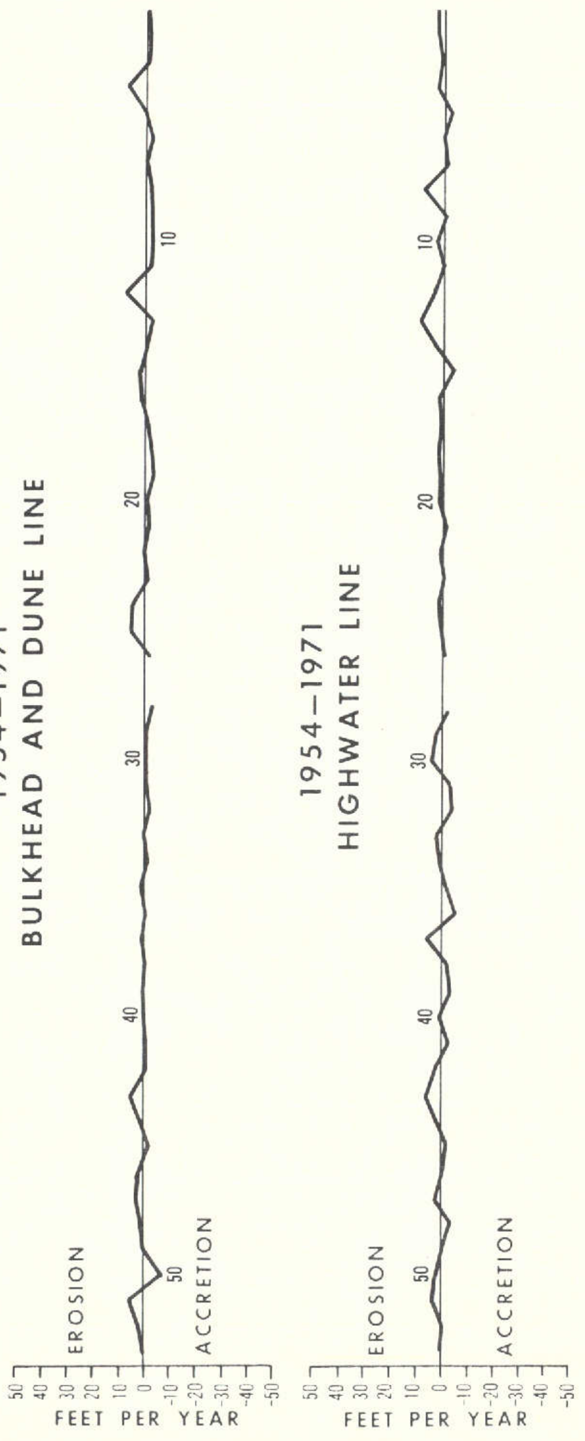

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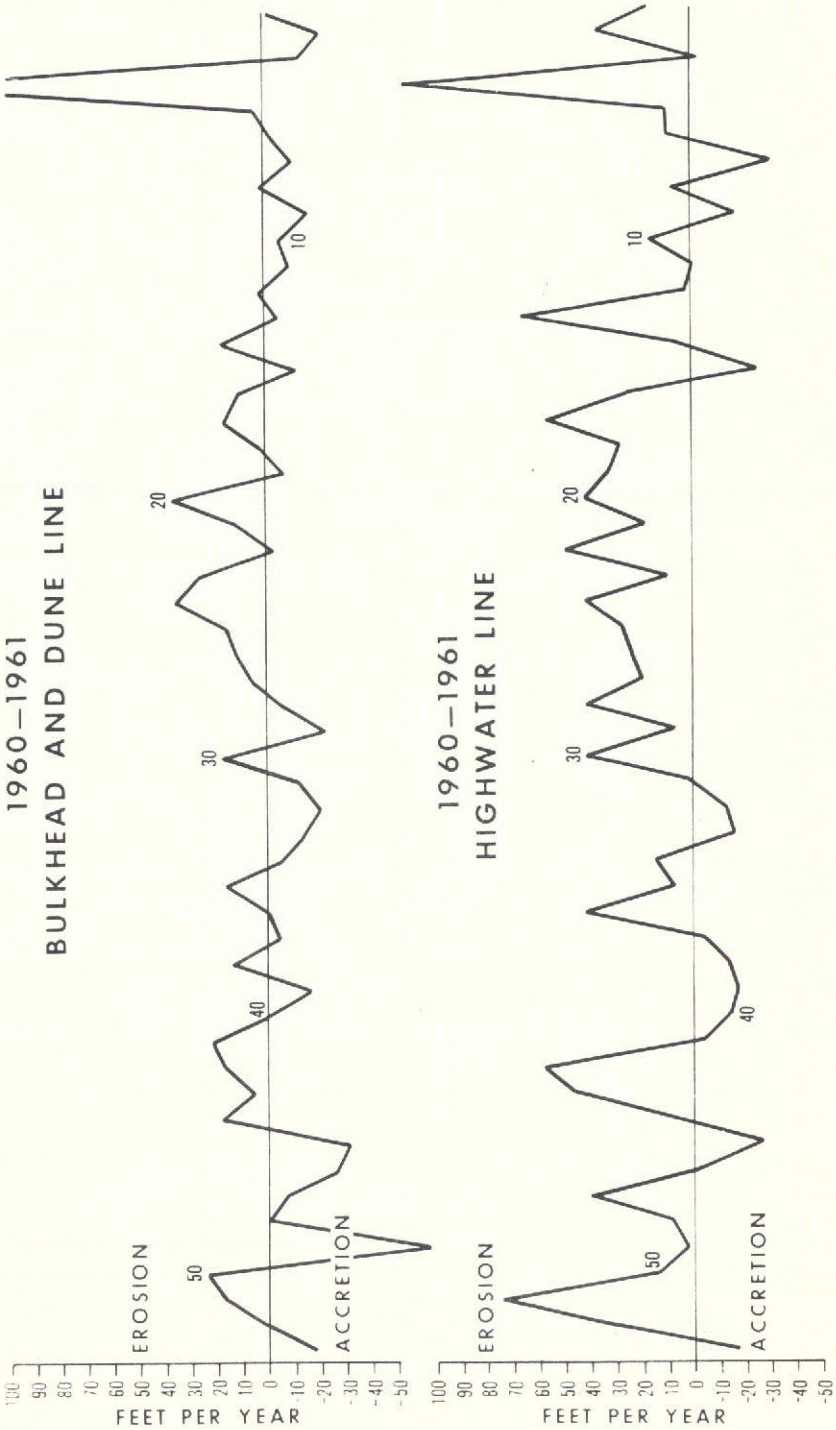

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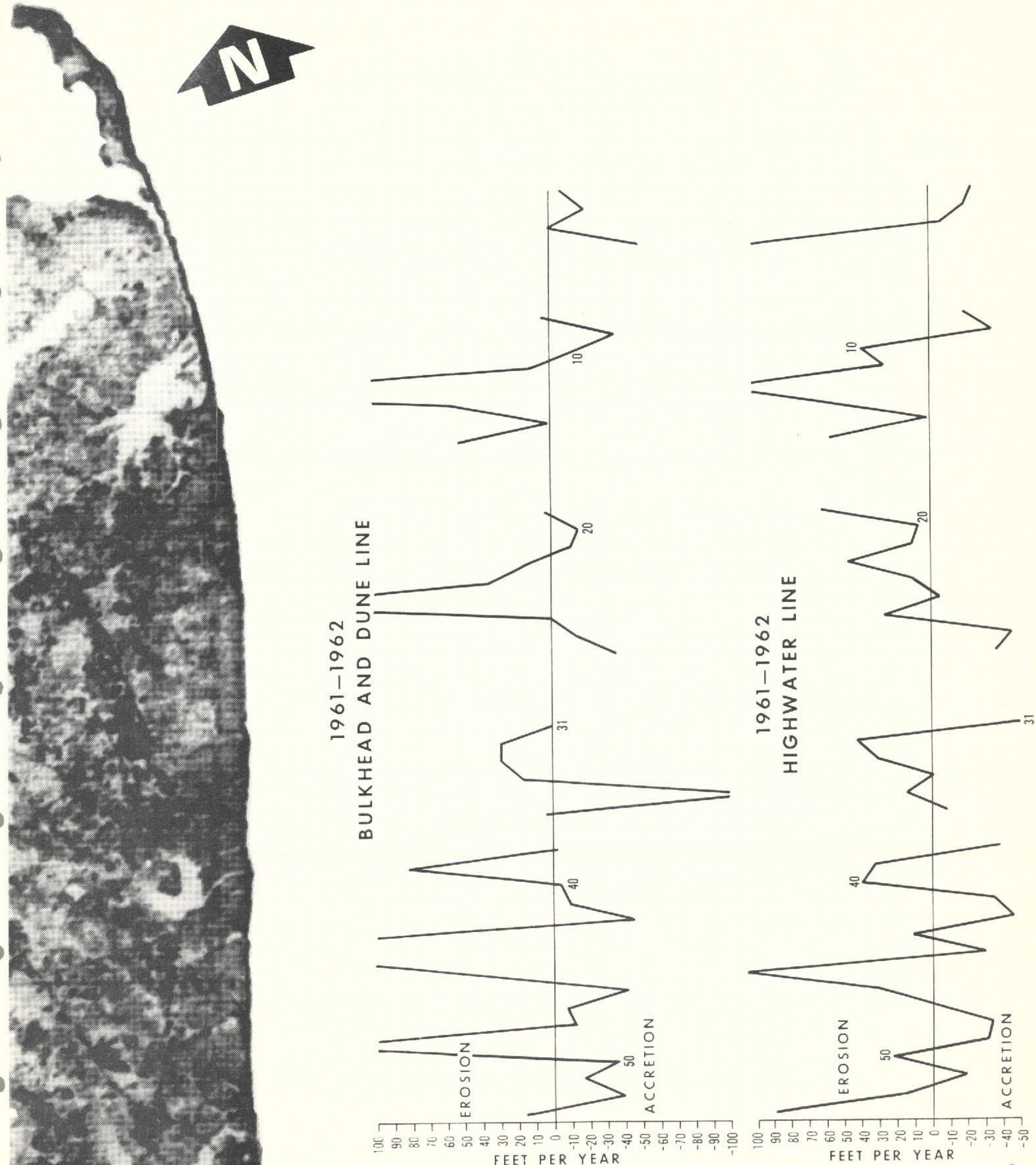

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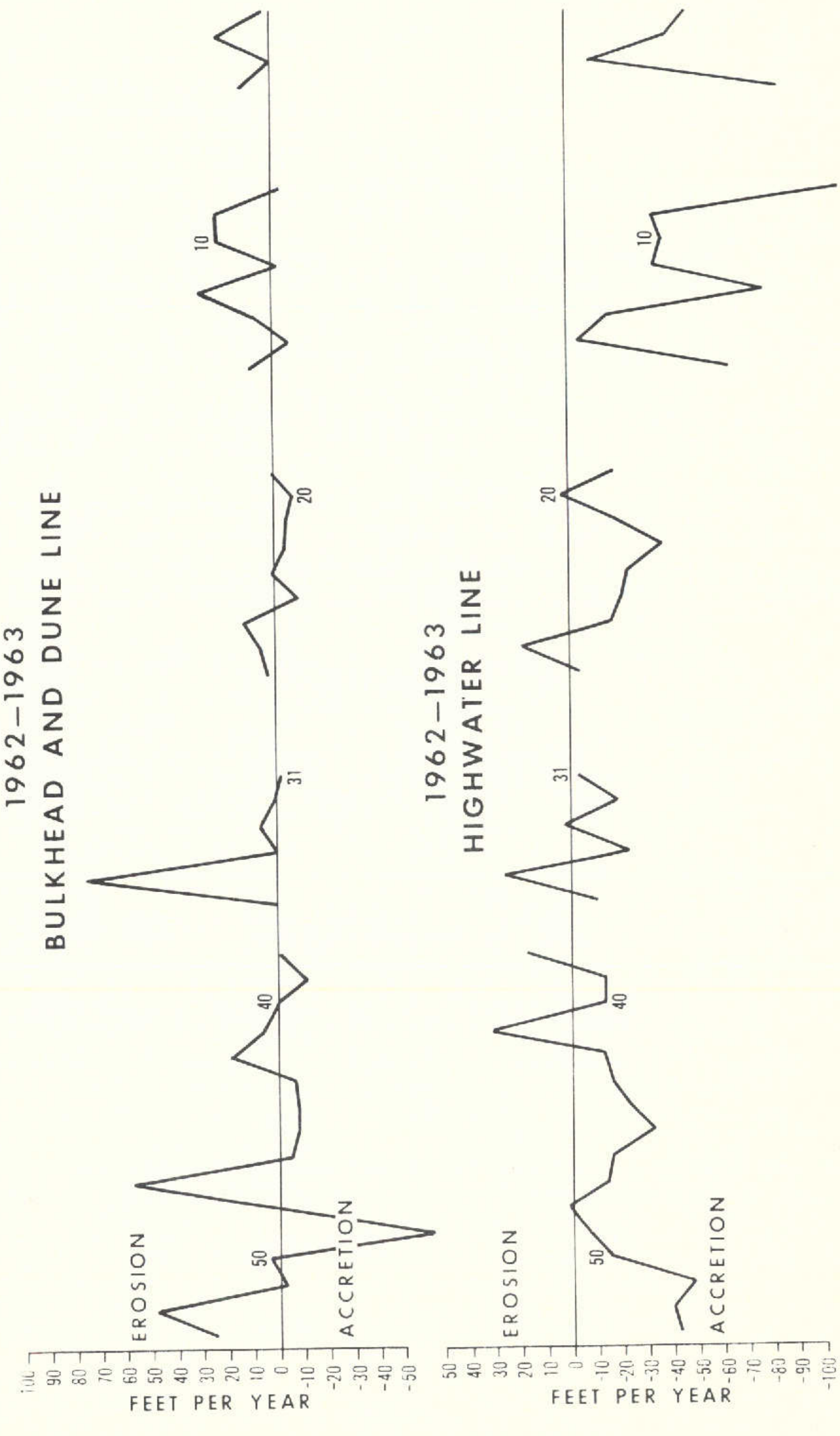

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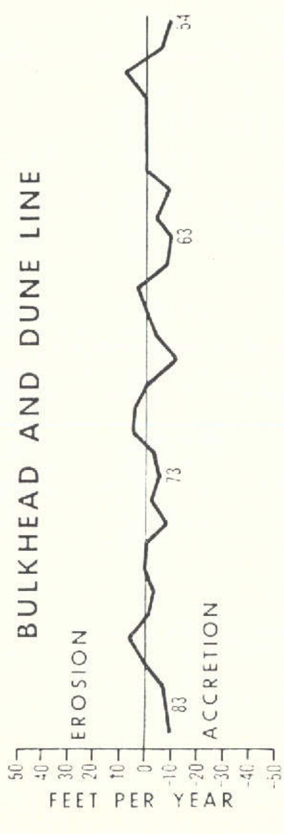

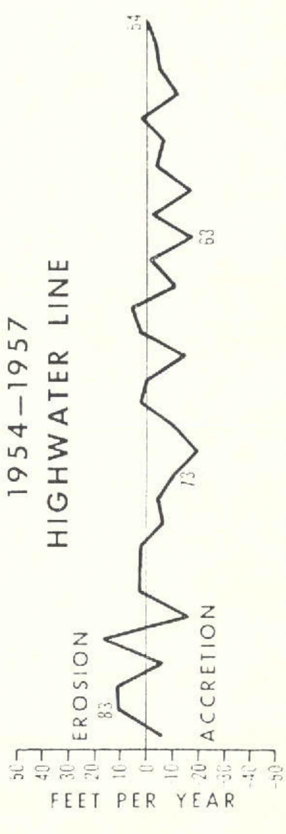

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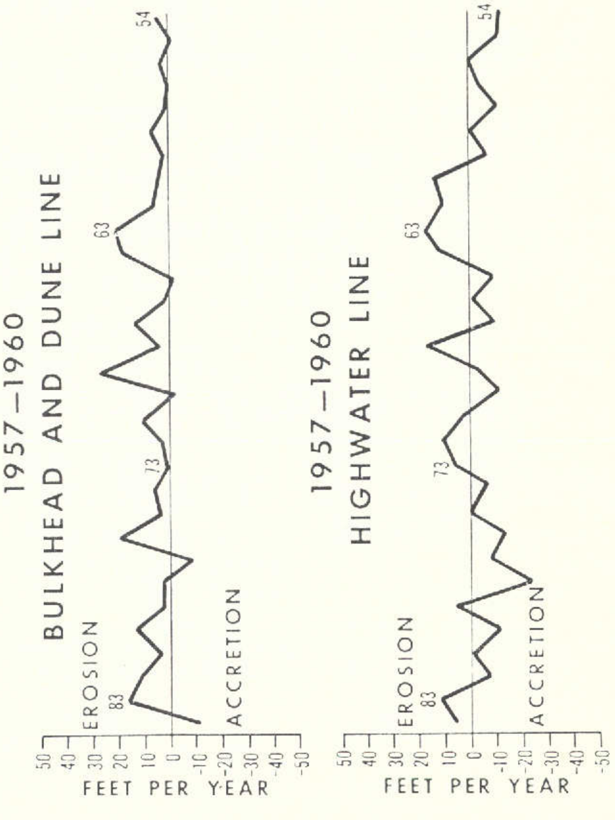

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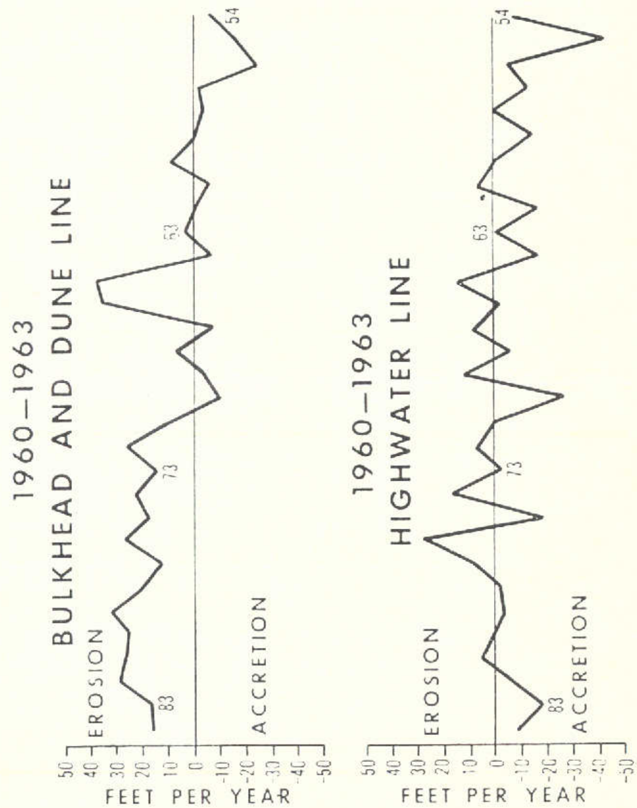

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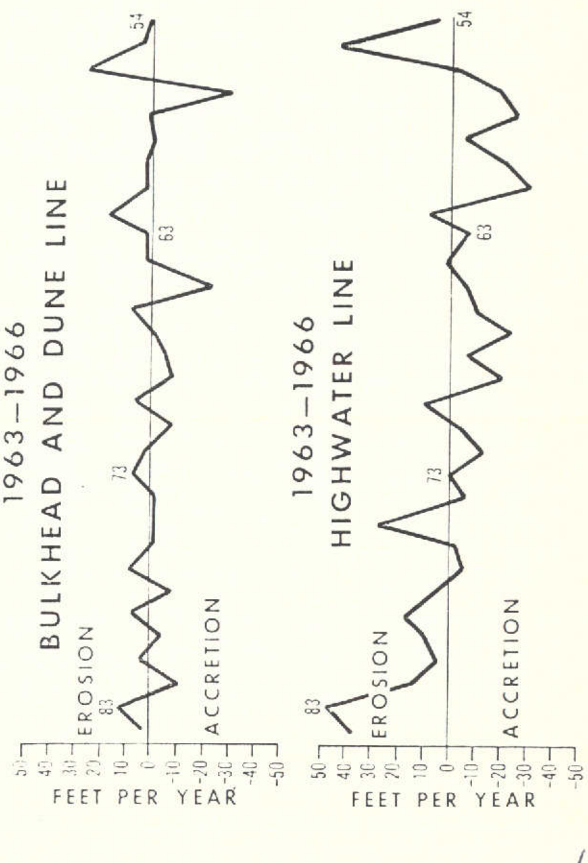

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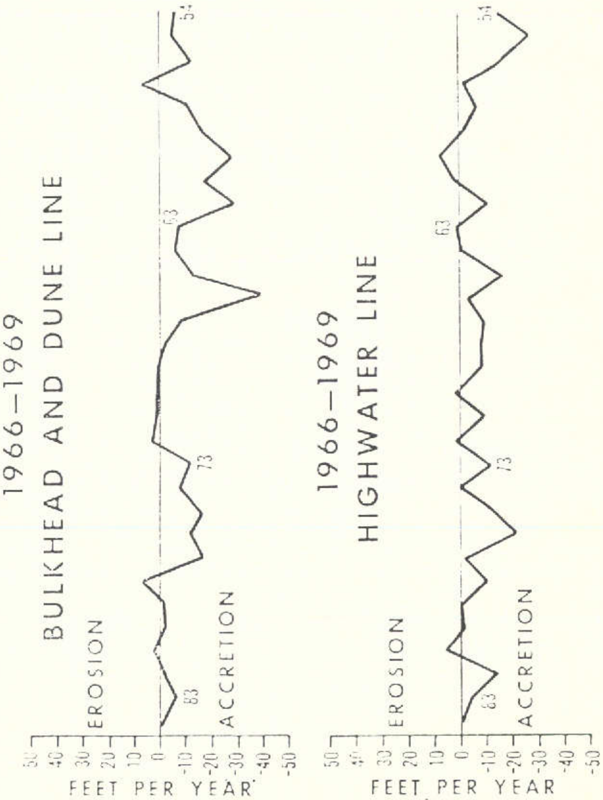

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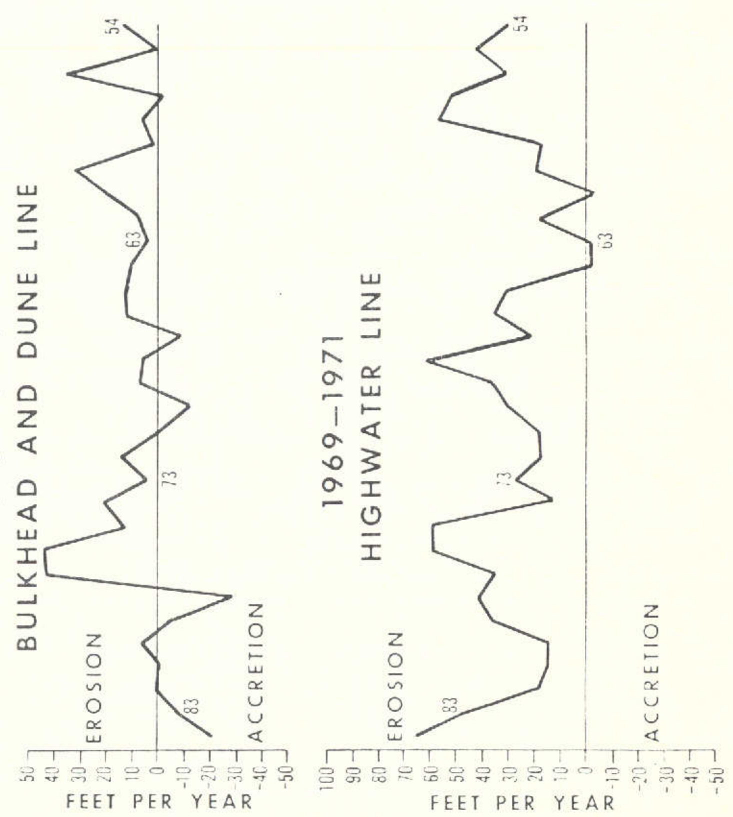

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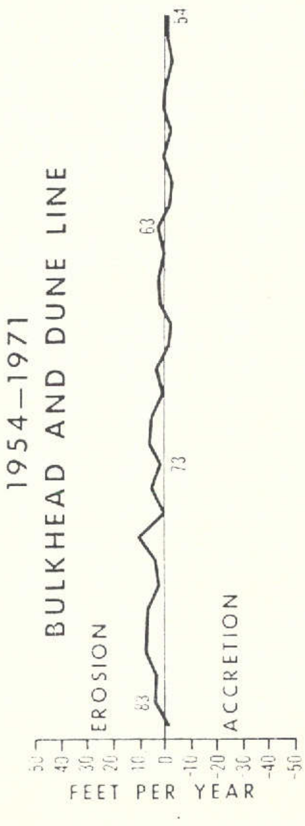

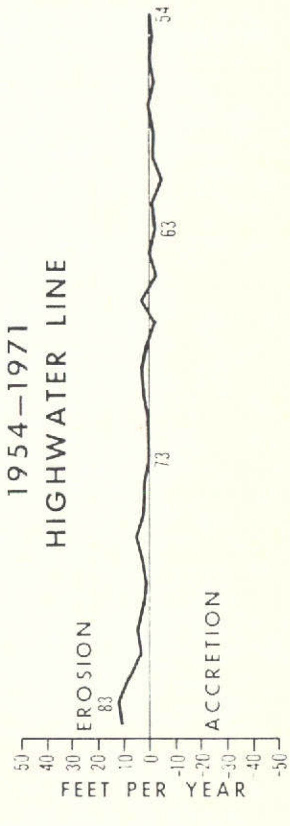

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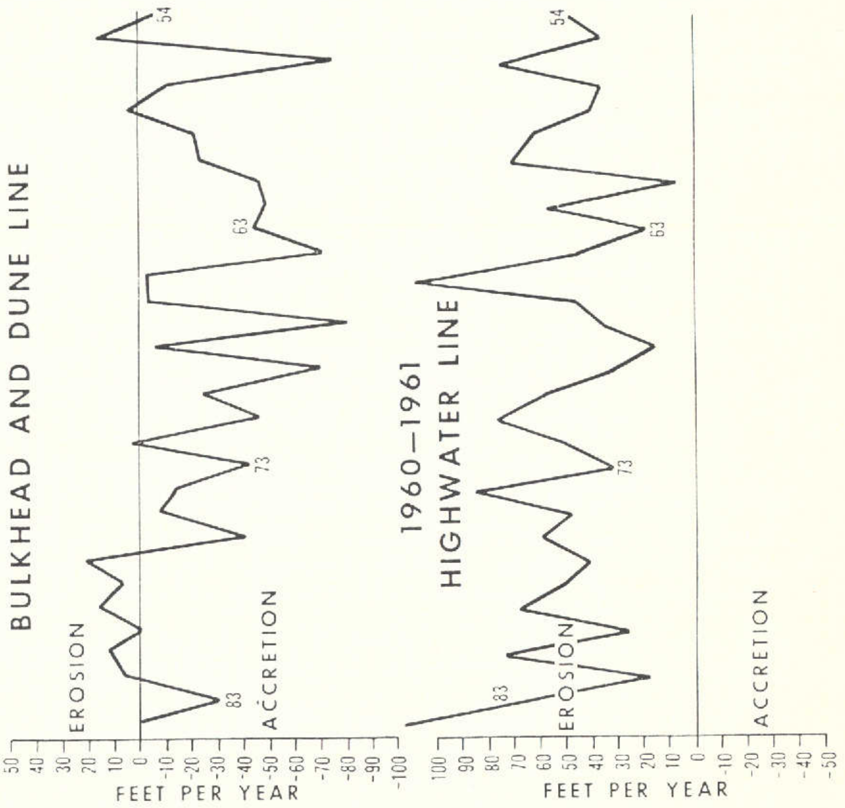

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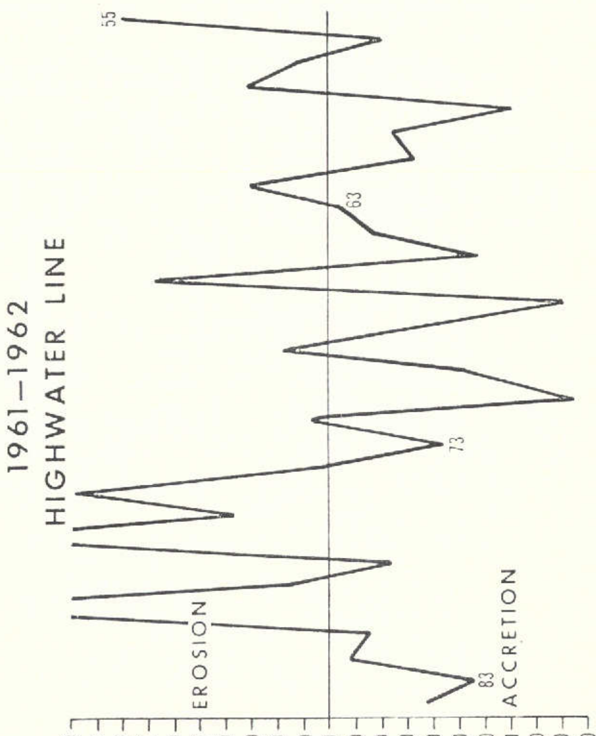

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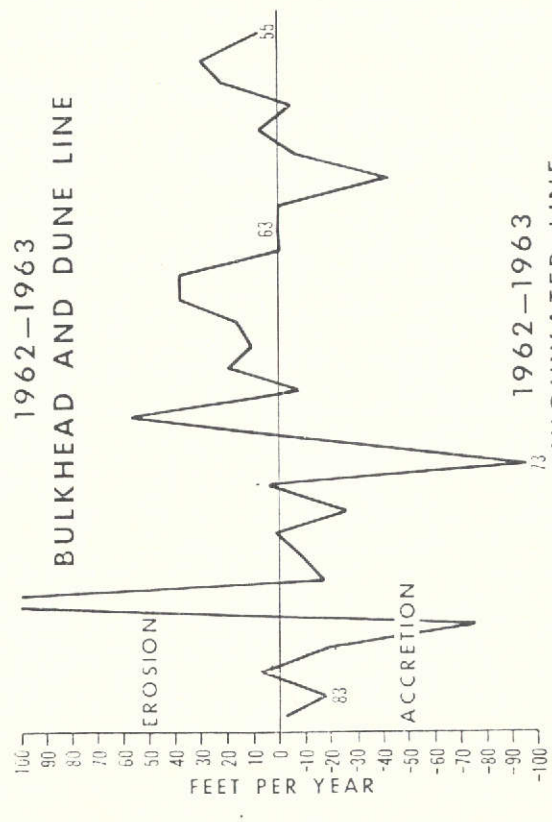

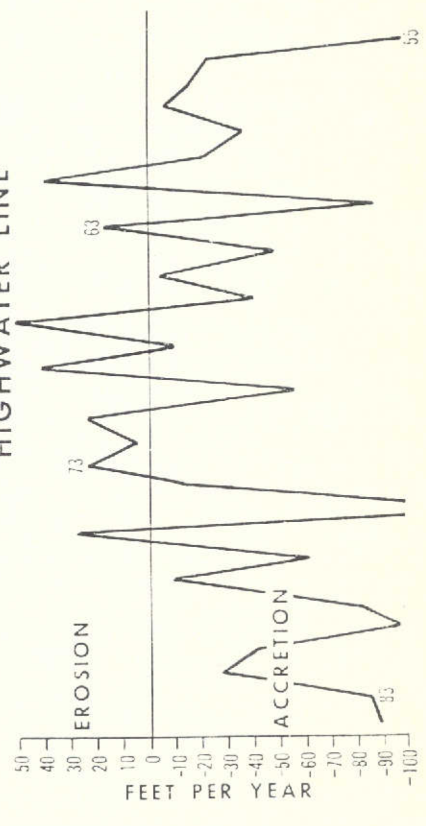

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EARTH SATELLITE CORPORATION
1747 Pennsylvania Avenue
Washington, D.C. 20006

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGHWATER LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1954 TO 1957
TIME INTERVAL: 3.67 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-14.30	-3.90	28	-75.44	-20.55
2	28.80	7.85	29	-5.49	-1.50
3	-26.45	-7.21	30	-11.81	-3.22
4	44.11	12.02	31	-28.71	-7.82
5	-28.06	-7.64	32	-44.07	-12.01
6	76.16	20.75	33	-18.70	-5.10
7	-19.44	-5.30	34	-33.63	-9.16
8	59.48	16.21	35	-1.91	-0.52
9	-4.71	-1.28	36	-45.05	-12.27
10	30.54	8.32	37	-50.48	-13.75
11	-49.21	-13.41	38	-78.69	-21.44
12	-33.06	-9.01	39	-63.43	-17.28
13	7.42	2.02	40	-65.62	-17.88
14	-12.20	-3.32	41	-82.20	-22.40
15	1.99	0.54	42	2.23	0.61
16	-9.07	-2.47	43	57.99	15.80
17	-5.87	-1.60	44	33.07	9.01
18	-16.29	-4.44	45	-32.64	-8.89
19	-41.61	-11.34	46	33.34	9.08
20	-46.21	-12.59	47	3.56	0.97
21	-15.29	-4.17	48	-31.18	-8.50
22	-99.08	-27.00	49	-26.18	-7.13
23	-47.26	-12.88	50	5.29	1.44
24	1.33	0.36	51	6.73	1.83
25	-46.81	-12.75	52	-8.77	-2.39
26	-67.32	-18.34	53	-30.81	-8.39
27	No Data	No Data			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1954 TO 1957
TIME INTERVAL: 3.67 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-11.82	-3.22	28	-6.80	-1.85
2	-16.46	-4.48	29	-2.97	-0.81
3	-5.37	-1.46	30	1.77	0.48
4	-21.85	-5.95	31	1.81	0.49
5	13.56	3.70	32	-18.43	-5.02
6	9.15	2.49	33	1.51	0.41
7	-2.97	-0.81	34	-22.04	-6.00
8	-14.13	-3.85	35	51.30	13.98
9	-24.66	-6.72	36	-7.50	-2.04
10	-37.76	-10.29	37	-29.59	-8.06
11	-2.44	-0.67	38	1.78	0.49
12	1.83	0.50	39	-8.12	-2.21
13	-90.83	-24.75	40	-0.81	-0.22
14	-27.75	-7.56	41	-17.61	-4.80
15	-19.51	-5.32	42	-3.81	-1.04
16	-0.56	-0.15	43	-7.38	-2.01
17	-9.46	-2.58	44	-8.21	-2.24
18	-26.46	-7.21	45	-15.05	-4.10
19	-44.10	-12.02	46	49.12	13.38
20	-17.00	-4.63	47	-12.60	-3.43
21	-7.98	-2.17	48	21.73	5.92
22	-15.48	-4.22	49	0.13	0.03
23	-2.84	-0.77	50	-71.79	-19.56
24	1.33	0.36	51	89.16	24.29
25	-60.00	-16.35	52	63.23	17.23
26	-26.73	-7.28	53	4.76	1.30
27	No Data	No Data			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGHWATER LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1957 TO 1960
TIME INTERVAL: 2.16 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	48.80	22.59	28	-73.98	-34.25
2	-3.91	-1.81	29	-44.54	-20.62
3	18.66	8.64	30	31.43	14.55
4	-30.48	-14.11	31	-6.83	-3.16
5	20.59	9.53	32	-38.29	-17.73
6	-59.17	-27.39	33	7.12	3.30
7	-62.46	-28.92	34	-16.22	-7.51
8	5.84	2.70	35	-124.31	-57.55
9	18.93	8.76	36	-141.01	-65.28
10	-10.78	-4.99	37	178.58	82.68
11	26.05	12.06	38	48.85	22.62
12	20.68	9.57	39	30.92	14.31
13	33.91	15.70	40	22.09	10.23
14	9.85	4.56	41	58.49	27.08
15	-27.46	-12.71	42	24.28	11.24
16	-6.33	-2.93	43	5.95	2.76
17	-28.01	-12.97	44	7.85	3.64
18	27.68	12.81	45	-9.82	-4.55
19	-5.22	-2.42	46	-42.48	-19.67
20	7.59	3.52	47	18.22	8.44
21	-4.43	-2.05	48	8.04	3.72
22	50.38	23.33	49	5.30	2.46
23	14.41	6.67	50	-6.02	-2.79
24	-28.25	-13.08	51	-47.50	-21.99
25	-22.39	-10.37	52	-9.09	-4.21
26	17.83	8.26	53	-9.68	-4.48
27	-10.74	-4.97			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1957 TO 1960
TIME INTERVAL: 2.16 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	6.43	2.98	28	-32.20	-14.91
2	16.46	7.62	29	-13.60	-6.29
3	8.12	3.76	30	-15.37	-7.12
4	-65.75	-30.44	31	-22.42	-10.38
5	-25.46	-11.79	32	-7.99	-3.70
6	-13.60	-6.30	33	3.91	1.81
7	3.03	1.40	34	8.87	4.11
8	1.66	0.77	35	-12.02	-5.56
9	18.93	8.76	36	7.41	3.43
10	12.07	5.59	37	12.15	5.63
11	7.31	3.39	38	-14.08	-6.52
12	-13.57	-6.28	39	8.83	4.09
13	1.13	0.52	40	0.95	0.44
14	58.62	27.14	41	2.00	0.93
15	14.23	6.59	42	-5.63	-2.60
16	5.50	2.55	43	5.08	2.35
17	18.23	8.44	44	-5.02	-2.32
18	17.68	8.18	45	16.84	7.80
19	-1.68	-0.78	46	-10.29	-4.76
20	30.82	14.27	47	8.62	3.99
21	6.10	2.83	48	4.03	1.87
22	9.23	4.27	49	55.92	25.89
23	-25.70	-11.90	50	-15.83	-7.33
24	-22.48	-10.41	51	5.41	2.50
25	162.78	75.36	52	-0.23	-0.11
26	-1.92	-0.89	53	-0.63	-0.29
27	1.63	0.75			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1960 TO 1963
TIME INTERVAL: 3.41 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-49.12	-14.40	28	53.31	15.63
2	-69.42	-20.36	29	-22.46	-6.59
3	-15.17	-4.45	30	-5.99	-1.76
4	37.74	11.07	31	-26.66	-7.82
5	-62.35	-18.28	32	-11.70	-3.43
6	-108.32	-31.77	33	4.69	1.37
7	-90.31	-26.48	34	-14.27	-4.18
8	-122.04	-35.79	35	43.47	12.75
9	-68.11	-19.97	36	27.06	7.93
10	-10.18	-2.99	37	-85.87	-25.18
11	-27.85	-8.17	38	14.11	4.14
12	-24.58	-7.21	39	-14.94	-4.38
13	67.72	19.86	40	-9.24	-2.71
14	0.82	0.24	41	37.24	10.92
15	-67.37	-19.76	42	13.01	3.82
16	17.78	5.21	43	27.36	8.02
17	42.25	12.39	44	-32.32	-9.48
18	14.26	4.18	45	-11.25	-3.30
19	35.96	10.54	46	-5.56	-1.63
20	40.70	11.93	47	17.61	5.16
21	1.16	0.34	48	-6.58	-1.93
22	20.93	6.14	49	-19.49	-5.72
23	-12.35	-3.62	50	4.33	1.27
24	9.09	2.67	51	-1.35	-0.39
25	15.66	4.59	52	-9.91	-2.91
26	20.59	6.04	53	-22.68	-6.65
27	-5.21	-1.53			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1960 TO 1963
TIME INTERVAL: 3.41 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-3.99	-1.17	28	-9.89	-2.90
2	-44.68	-13.10	29	-14.51	-4.26
3	-10.30	-3.02	30	8.14	2.39
4	187.68	55.04	31	-12.89	-3.78
5	36.27	10.64	32	-3.28	-0.96
6	10.81	3.17	33	7.53	2.21
7	-6.85	-2.01	34	2.27	0.67
8	-0.97	-0.28	35	44.00	12.90
9	-6.73	-1.97	36	0.54	0.16
10	12.02	3.52	37	0.99	0.29
11	-6.66	-1.95	38	7.76	2.28
12	155.25	45.53	39	8.32	2.44
13	27.40	8.04	40	-0.70	-0.20
14	6.97	2.05	41	19.55	5.73
15	21.04	6.17	42	14.85	4.35
16	24.31	7.13	43	43.42	12.73
17	5.54	1.63	44	73.91	21.67
18	-12.25	-3.59	45	-27.84	-8.17
19	-3.19	-0.93	46	-47.31	-13.87
20	14.90	4.37	47	48.74	14.29
21	-1.04	-0.30	48	28.71	8.42
22	3.68	1.08	49	-102.94	-30.19
23	38.44	11.27	50	7.58	2.22
24	100.08	29.35	51	3.34	0.98
25	-109.65	-32.15	52	37.29	10.93
26	9.33	2.74	53	20.21	5.93
27	-17.59	-5.16			

RATES OF CHANGE IN FEET PER YEAR FOR

THE HIGHWATER LINE

FROM HIGHLANDS BEACH TO MANASQUAN INLET

1963 TO 1966

TIME INTERVAL: 2.88 YEARS

NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	59.60	20.70	28	-28.59	-9.93
2	91.33	31.71	29	32.05	11.13
3	-2.20	-0.76	30	42.02	14.59
4	-68.58	-23.81	31	-11.60	-4.03
5	-26.75	-9.29	32	-2.18	-0.76
6	27.12	9.42	33	-1.87	-0.65
7	63.21	21.95	34	25.80	8.96
8	46.04	15.99	35	15.46	5.37
9	41.58	14.44	36	0.95	0.33
10	25.71	8.93	37	4.24	1.47
11	37.80	13.13	38	-39.84	-13.83
12	66.13	22.96	39	-13.37	-4.64
13	9.35	3.25	40	56.34	19.56
14	18.67	6.48	41	7.63	2.65
15	5.27	1.83	42	-9.28	-3.22
16	-27.92	-9.69	43	-7.35	-2.55
17	-21.88	-7.60	44	13.04	4.53
18	-6.29	-2.18	45	5.39	1.87
19	-1.69	-0.59	46	0.43	0.15
20	-5.53	-1.92	47	5.35	1.86
21	-9.47	-3.29	48	-7.26	-2.52
22	11.99	4.16	49	15.46	5.37
23	8.49	2.95	50	-50.48	-17.53
24	3.21	1.12	51	57.79	20.06
25	5.04	1.75	52	18.85	6.55
26	-16.74	-5.81	53	23.49	8.16
27	6.17	2.14			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1963 TO 1966
TIME INTERVAL: 2.88 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-6.94	-2.41	28	9.51	3.30
2	18.09	6.28	29	-4.05	-1.41
3	6.66	2.31	30	-3.45	-1.20
4	-6.81	-2.37	31	4.01	1.39
5	-9.63	-3.34	32	-0.63	-0.22
6	-39.06	-13.56	33	11.13	3.86
7	2.23	0.77	34	2.72	0.95
8	1.74	0.60	35	3.38	1.17
9	-19.80	-6.88	36	-12.32	-4.28
10	-18.31	-6.36	37	5.96	2.07
11	-12.60	-4.37	38	0.31	0.11
12	-1.71	-0.59	39	-14.75	-5.12
13	5.91	2.05	40	0.43	0.15
14	3.60	1.25	41	22.31	7.75
15	9.14	3.17	42	-5.48	-1.90
16	-7.55	-2.62	43	19.88	6.90
17	-1.00	-0.35	44	-7.49	-2.60
18	2.06	0.71	45	30.63	10.63
19	4.27	1.48	46	29.15	10.12
20	-5.26	-1.83	47	7.44	2.58
21	-9.44	-3.28	48	-22.06	-7.66
22	-2.04	-0.71	49	57.44	19.95
23	1.82	0.63	50	7.42	2.58
24	2.73	0.95	51	14.48	5.03
25	91.12	31.64	52	8.14	2.83
26	-8.80	-3.06	53	18.22	6.33
27	6.96	2.42			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGHWATER LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1966 TO 1969
TIME INTERVAL: 3.48 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-62.84	-18.06	28	5.12	1.47
2	-33.99	-9.77	29	5.52	1.59
3	17.01	4.89	30	-11.35	-3.26
4	18.33	5.27	31	6.91	1.99
5	22.98	6.60	32	-13.04	-3.75
6	-6.44	-1.85	33	-36.23	-10.41
7	-10.19	-2.93	34	-34.64	-9.95
8	52.65	15.13	35	-4.86	-1.40
9	-5.30	-1.52	36	35.51	10.20
10	3.39	0.97	37	-19.35	-5.56
11	1.69	0.49	38	-18.88	-5.42
12	13.09	3.76	39	-26.51	-7.62
13	18.33	5.27	40	-4.78	-1.37
14	-24.32	-6.99	41	-56.66	-16.28
15	-29.08	-8.36	42	1.36	0.39
16	58.64	16.85	43	3.62	1.04
17	13.91	4.00	44	-11.35	-3.26
18	-8.20	-2.36	45	-19.41	-5.58
19	-14.59	-4.19	46	-30.15	-8.66
20	-38.17	-10.97	47	3.32	0.96
21	-55.07	-15.82	48	-12.69	-3.65
22	-28.50	-8.19	49	-16.47	-4.73
23	0.56	0.16	50	38.92	11.18
24	3.09	0.89	51	-5.02	-1.44
25	2.41	0.69	52	-37.34	-10.73
26	4.60	1.32	53	-19.84	-5.70
27	0.01	0.00			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1966 TO 1969
TIME INTERVAL: 3.48 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	9.09	2.61	28	2.99	0.86
2	17.92	5.15	29	16.77	4.82
3	-8.62	-2.48	30	7.23	2.08
4	5.09	1.46	31	9.34	2.68
5	2.55	0.73	32	1.33	0.38
6	3.90	1.12	33	-19.85	-5.70
7	1.51	0.44	34	-8.52	-2.45
8	3.28	0.94	35	0.62	0.18
9	-5.30	-1.52	36	14.14	4.06
10	2.96	0.85	37	-16.29	-4.68
11	7.16	2.06	38	4.42	1.27
12	-3.07	-0.88	39	4.53	1.30
13	-2.60	-0.75	40	1.20	0.34
14	-2.08	-0.60	41	-17.52	-5.03
15	15.52	4.46	42	3.85	1.11
16	13.03	3.74	43	7.51	2.16
17	0.70	0.20	44	-30.58	-8.79
18	4.17	1.20	45	-20.72	-5.95
19	5.26	1.51	46	12.39	3.56
20	-12.78	-3.67	47	-4.72	-1.36
21	9.46	2.72	48	-6.93	-1.99
22	13.54	3.89	49	7.81	2.24
23	-3.68	-1.06	50	35.98	10.34
24	6.52	1.87	51	-22.67	-6.51
25	-1.83	-0.53	52	-37.25	-10.70
26	-5.08	-1.46	53	-31.93	-9.18
27	-0.78	-0.22			

RATES OF CHANGE IN FEET PER YEAR FOR

THE HIGH WATERLINE

FROM HIGHLANDS BEACH TO MANASQUAN INLET

1954 TO 1971

TIME INTERVAL: 16.92 YEARS

NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	62.51	3.69	28	-25.74	-1.52
2	55.81	3.30	29	46.44	2.74
3	19.85	1.17	30	82.98	4.90
4	58.84	3.48	31	-34.73	-2.05
5	-35.98	-2.13	32	-66.48	-3.93
6	11.28	0.67	33	40.77	2.41
7	-19.79	-1.17	34	30.86	1.82
8	134.65	7.96	35	-10.87	-0.64
9	-4.82	-0.28	36	-77.00	-4.55
10	49.89	2.95	37	94.07	5.56
11	9.68	0.57	38	-21.92	-1.30
12	72.37	4.28	39	-48.96	-2.89
13	164.47	9.72	40	16.62	0.98
14	54.29	3.21	41	-20.53	-1.21
15	-70.84	-4.19	42	61.15	3.61
16	46.99	2.78	43	101.16	5.98
17	17.65	1.04	44	41.97	2.48
18	29.67	1.75	45	-12.92	-0.76
19	24.36	1.44	46	-3.95	-0.23
20	25.02	1.48	47	48.72	2.88
21	-16.83	-0.99	48	-55.08	-3.26
22	19.20	1.13	49	3.82	0.23
23	11.30	0.67	50	32.96	1.95
24	19.75	1.17	51	41.77	2.47
25	19.13	1.13	52	-6.49	-0.38
26	-11.33	-0.67	53	6.94	0.41
27	No Data	No Data			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1954 TO 1971
TIME INTERVAL: 16.92 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-13.75	-0.81	28	-38.96	-2.30
2	-17.59	-1.04	29	-3.71	-0.22
3	-6.03	-0.36	30	-5.06	-0.30
4	109.71	6.48	31	-4.60	-0.27
5	20.37	1.20	32	-25.49	-1.51
6	-25.72	-1.52	33	0.79	0.05
7	-3.13	-0.18	34	-11.25	-0.66
8	-22.07	-1.30	35	23.56	1.39
9	-24.77	-1.46	36	-3.49	-0.21
10	-38.17	-2.26	37	-19.27	-1.14
11	-21.88	-1.29	38	-2.57	-0.15
12	144.16	8.52	39	4.50	0.27
13	-53.00	-3.13	40	6.02	0.36
14	-14.71	-0.87	41	-5.85	-0.35
15	30.00	1.77	42	-1.00	-0.06
16	25.30	1.50	43	86.72	5.13
17	-13.74	-0.81	44	24.07	1.42
18	-48.71	-2.88	45	-19.19	-1.13
19	-51.59	-3.05	46	22.95	1.36
20	-1.63	-0.10	47	41.59	2.46
21	-13.84	-0.82	48	24.36	1.44
22	7.00	0.41	49	5.92	0.35
23	-9.61	-0.57	50	-98.57	-5.83
24	85.76	5.07	51	97.50	5.76
25	99.57	5.88	52	38.75	2.29
26	-33.01	-1.95	53	4.04	0.24
27	No Data	No Data			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGHWATER LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1960 TO 1961
TIME INTERVAL: 0.83 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
1	14.57	17.55	28	34.94	42.10
2	31.01	37.37	29	5.52	6.65
3	-2.48	-2.99	30	34.16	41.16
4	92.89	111.92	31	-0.11	-0.13
5	8.43	10.03	32	-10.25	-12.35
6	8.02	9.66	33	-13.51	-16.28
7	-25.86	-31.16	34	12.38	14.92
8	7.04	8.48	35	7.02	8.46
9	-14.05	-16.93	36	34.47	41.53
10	14.37	17.32	37	-3.60	-4.34
11	-0.57	-0.68	38	11.76	14.16
12	1.63	1.96	39	-13.99	-16.86
13	55.49	66.86	40	-11.71	-14.11
14	4.94	5.95	41	-4.02	-4.84
15	-21.06	-25.38	42	48.78	58.77
16	21.20	25.55	43	39.31	47.37
17	47.06	56.69	44	7.55	9.10
18	24.33	29.31	45	-23.10	-27.83
19	27.99	33.72	46	-1.45	-1.74
20	34.49	41.55	47	34.14	41.13
21	16.49	19.87	48	7.24	8.72
22	40.86	49.22	49	3.21	3.87
23	9.04	10.90	50	12.41	14.95
24	35.25	42.48	51	62.46	75.26
25	22.53	27.15	52	28.55	34.39
26	20.04	24.14	53	-14.30	-17.23
27	16.84	20.29			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1960 TO 1961
TIME INTERVAL: 0.83 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
1	-2.92	-3.52	28	-4.35	-5.25
2	-17.50	-21.08	29	-18.31	-22.06
3	-11.07	-13.34	30	14.36	17.30
4	116.06	139.83	31	-10.17	-12.25
5	3.71	4.47	32	-16.86	-20.32
6	-2.43	-2.93	33	-11.71	-14.11
7	-8.56	-10.32	34	-4.20	-5.06
8	1.50	1.80	35	13.25	15.97
9	-14.05	-16.93	36	-0.07	-0.08
10	-4.90	-5.91	37	-4.07	-4.91
11	-8.27	-9.97	38	11.09	13.36
12	1.63	1.96	39	-13.27	-15.99
13	-4.46	-5.38	40	0.72	0.87
14	13.92	16.77	41	17.81	21.45
15	-11.53	-13.89	42	14.64	17.64
16	9.55	11.50	43	4.63	5.57
17	14.18	17.08	44	14.99	18.06
18	1.79	2.16	45	-25.80	-31.09
19	-5.56	-6.70	46	-21.89	-26.37
20	29.90	36.02	47	-5.55	-6.69
21	9.92	11.95	48	0.10	0.12
22	2.23	2.68	49	-53.49	-64.45
23	21.50	25.90	50	20.21	24.35
24	29.48	35.52	51	14.35	17.29
25	12.87	15.51	52	1.02	1.23
26	9.61	11.58	53	-15.09	-18.19
27	4.47	5.38			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1961 TO 1962
TIME INTERVAL: 0.45 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Project. Rate/Yr.
1	-11.23	-24.95	25	12.20	27.11
2	-8.69	-19.31	26	-20.60	-45.78
3	-2.76	-6.13	27	-16.74	-37.20
4	45.45	100.99	28	No Data	No Data
5	No Data	No Data	29	No Data	No Data
6	No Data	No Data	30	No Data	No Data
7	No Data	No Data	31	-23.04	-51.19
8	-8.23	-18.28	32	19.36	43.03
9	-16.42	-36.49	33	14.03	31.17
10	17.58	39.07	34	-0.79	-1.76
11	11.67	25.94	35	6.71	14.91
12	60.39	134.19	36	27.02	-8.75
13	29.86	66.35	37	No Data	No Data
14	1.09	2.43	38	-17.34	-38.54
15	25.90	57.56	39	14.72	32.71
16	No Data	No Data	40	17.55	39.00
17	No Data	No Data	41	-16.01	-35.27
18	No Data	No Data	42	-21.21	-47.13
19	28.42	63.15	43	5.56	12.36
20	2.97	6.59	44	-13.72	-30.50
21	5.11	11.35	45	48.55	107.89
22	21.43	47.63	46	14.71	32.68
23	4.68	10.39	47	-0.64	-1.43
24	-2.30	-5.11	48	-15.46	-34.35
				-14.25	-31.68

RATES OF CHANGE IN FEET PER YEAR FOR

THE HIGH WATERLINE

FROM HIGHLANDS BEACH TO MANASQUAN INLET

1961 TO 1962

TIME INTERVAL: 0.45 YEARS

NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
49	-14.25	-31.38			
50	10.51	23.26			
51	-8.95	-19.89			
52	6.40	14.23			
53	40.09	89.09			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1961 TO 1962
TIME INTERVAL: 0.45 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.
1	-3.40	-7.55
2	-8.69	-19.31
3	0.85	1.89
4	-23.32	-51.81
5	No Data	No Data
6	No Data	No Data
7	No Data	No Data
8	2.37	5.26
9	-16.42	-36.49
10	-5.77	-12.81
11	4.98	11.07
12	121.16	269.23
13	25.57	56.82
14	0.96	2.12
15	23.58	52.39
16	No Data	No Data
17	No Data	No Data
18	No Data	No Data
19	1.65	3.66
20	-6.80	-15.11
21	-4.92	-10.93
22	6.61	14.70
23	16.13	35.84
24	81.16	180.36
25	-0.67	-1.50
26	-6.43	-14.30
27	-16.74	-37.20
28	No Data	No Data
29	No Data	No Data
30	No Data	No Data
31	0.23	0.51
32	13.45	29.88
33	13.08	29.08
34	7.78	17.30
35	-52.55	-116.77
36	1.42	3.16
37	No Data	No Data
38	-1.27	-2.82
39	36.06	80.12
40	-2.10	-4.66
41	-4.20	-9.33
42	-20.89	-46.42
43	47.04	104.53
44	68.22	151.60
45	19.18	42.61
46	-18.93	-42.06
47	-3.20	-7.11
48	-5.77	-12.83

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1961 TO 1962
TIME INTERVAL: 0.45 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
49	57.64	128.08			
50	-16.83	-37.40			
51	-7.17	-15.94			
52	-17.71	-39.36			
53	7.56	16.81			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	-52.46	-46.84	25	-19.07	-17.03
2	-43.01	-38.40	26	21.15	18.89
3	-9.93	-8.86	27	-5.32	-4.75
4	-93.70	-83.66	28	No Data	No Data
5	No Data	No Data	29	No Data	No Data
6	No Data	No Data	30	No Data	No Data
7	No Data	No Data	31	-3.51	-3.13
8	-120.84	-107.89	32	-20.81	-18.58
9	-37.64	-33.60	33	4.17	3.73
10	-42.13	-37.62	34	-25.86	-23.09
11	-38.95	-34.78	35	29.74	26.55
12	-86.59	-77.31	36	-11.57	-10.33
13	-17.63	-15.74	37	No Data	No Data
14	-5.21	-4.65	38	19.70	17.59
15	-72.21	-64.47	39	-15.67	-13.99
16	No Data	No Data	40	-15.08	-13.46
17	No Data	No Data	41	35.79	31.95
18	No Data	No Data	42	-14.56	-13.00
19	-20.45	-18.26	43	-17.52	-15.64
20	3.24	2.90	44	-26.15	-23.35
21	-20.44	-18.25	45	-36.71	-32.78
22	-41.36	-36.93	46	-18.82	-16.81
23	-26.07	-23.27	47	-15.88	-14.18
24	-23.87	-21.31	48	1.64	1.46

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
49	-8.45	-7.54			
50	-18.58	-16.59			
51	-54.86	-48.98			
52	-44.86	-40.06			
53	-48.47	-43.28			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
1	2.34	2.09	25	13.31	11.88
2	23.67	21.13	26	6.15	5.49
3	-0.07	-0.07	27	3.73	3.33
4	13.07	11.67	28	No Data	No Data
5	No Data	No Data	29	No Data	No Data
6	No Data	No Data	30	No Data	No Data
7	No Data	No Data	31	-2.95	-2.64
8	-4.83	-4.32	32	0.14	0.13
9	23.74	21.20	33	6.16	5.50
10	22.69	20.26	34	-1.31	-1.17
11	-3.37	-3.01	35	83.29	74.36
12	32.47	28.99	36	-0.82	-0.73
13	6.30	5.62	37	No Data	No Data
14	-7.90	-7.05	38	-2.06	-1.84
15	9.00	8.03	39	-14.46	-12.91
16	No Data	No Data	40	0.68	0.61
17	No Data	No Data	41	5.95	5.31
18	No Data	No Data	42	21.09	18.83
19	0.72	0.65	43	-8.25	-7.36
20	-8.20	-7.32	44	-9.30	-8.31
21	-6.04	-5.39	45	-9.31	-8.31
22	-5.16	-4.60	46	-6.49	-5.79
23	0.82	0.73	47	63.10	56.33
24	-10.56	-9.43	48	-0.93	-0.83

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
FROM HIGHLANDS BEACH TO MANASQUAN INLET
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
49	-69.39	-61.95			
50	4.19	3.74			
51	-3.84	-3.43			
52	53.98	48.19			
53	27.74	24.77			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1954 TO 1957
TIME INTERVAL: 3.67 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	0.50	0.14	79	-55.26	-15.06
55	-12.10	-3.30	80	64.56	17.59
56	-17.48	-4.76	81	-21.71	-5.92
57	-43.06	-11.73	82	43.76	11.92
58	9.33	2.54	83	39.39	10.73
59	-19.03	-5.18	84	-22.21	-6.05
60	-11.57	-3.15			
61	-56.77	-15.47			
62	-9.72	-2.65			
63	-59.46	-16.20			
64	-2.23	-0.61			
65	-39.93	-10.88			
66	26.47	7.21			
67	12.48	3.40			
68	-52.17	-14.22			
69	2.18	0.59			
70	11.79	3.21			
71	-38.30	-10.44			
72	-71.36	-19.44			
73	-39.21	-10.68			
74	-15.77	-4.30			
75	-21.97	-5.99			
76	7.36	2.01			
77	12.49	3.40			
78	12.64	3.44			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1954 TO 1957
INTERVAL: 3.67 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-33.94	-9.25	79	-4.75	-1.29
55	-19.45	-5.30	80	21.58	5.88
56	33.05	9.01	81	-0.50	-0.14
57	7.33	2.00	82	-25.08	-6.83
58	1.42	0.39	83	-31.95	-8.71
59	1.59	0.43	84	-33.13	-9.03
60	3.62	0.99			
61	-32.43	-8.84			
62	-16.17	-4.41			
63	-33.87	-9.23			
64	-30.76	-8.38			
65	16.81	4.58			
66	3.17	0.86			
67	-9.91	-2.70			
68	-40.57	-11.06			
69	-0.28	-0.08			
70	18.20	4.96			
71	18.80	5.12			
72	-13.10	-3.57			
73	-17.94	-4.89			
74	-10.61	-2.89			
75	-30.13	-8.21			
76	-0.66	-0.18			
77	-1.12	-0.31			
78	-10.89	-2.97			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1957 TO 1960
TIME INTERVAL: 2.16 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-26.58	-12.31	79	16.29	7.54
55	-25.76	-11.93	80	-24.70	-11.43
56	-0.54	-0.25	81	-1.84	-0.85
57	-8.63	-4.00	82	-16.19	-7.50
58	-23.51	-10.88	83	27.77	12.86
59	1.57	0.73	84	13.02	6.03
60	-13.62	-6.31			
61	29.61	13.71			
62	21.90	10.14			
63	35.30	16.34			
64	27.58	12.77			
65	-20.67	-9.57			
66	-2.36	-1.09			
67	-19.20	-8.89			
68	33.06	15.31			
69	-8.17	-3.78			
70	-23.74	-10.99			
71	8.39	3.88			
72	21.95	10.16			
73	14.45	6.69			
74	-13.66	-6.32			
75	-0.19	-0.09			
76	-28.14	-13.03			
77	-17.62	-8.16			
78	-52.94	-24.51			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1957 TO 1960
TIME INTERVAL: 2.16 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	10.79	4.99	79	6.52	3.02
55	-1.12	-0.52	80	30.22	13.99
56	6.82	3.16	81	8.80	4.08
57	0.44	0.20	82	22.10	10.23
58	4.46	2.07	83	35.09	16.25
59	16.55	7.66	84	-25.18	-11.66
60	7.13	3.30			
61	8.68	4.02			
62	14.59	6.76			
63	48.21	22.32			
64	41.59	19.25			
65	-3.42	-1.58			
66	4.97	2.30			
67	31.94	14.79			
68	9.69	4.49			
69	57.36	26.56			
70	-4.05	-1.87			
71	23.56	10.91			
72	6.48	3.00			
73	3.32	1.54			
74	12.01	5.56			
75	9.47	4.39			
76	44.73	20.71			
77	-17.82	-8.25			
78	5.89	2.73			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1960 TO 1963
TIME INTERVAL: 3.41 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-28.13	-8.25	79	-11.06	-3.24
55	-151.85	-44.53	80	3.20	0.94
56	-18.77	-5.50	81	13.95	4.09
57	-47.36	-13.89	82	-19.04	-5.58
58	0.81	0.24	83	-61.25	-17.96
59	-49.03	-14.38	84	-31.97	-9.38
60	-2.77	-0.81			
61	18.58	5.45			
62	-60.29	-17.68			
63	-9.32	-2.73			
64	-58.50	-17.16			
65	49.00	14.37			
66	-5.23	1.53			
67	28.39	8.32			
68	-19.30	-5.66			
69	40.75	11.95			
70	-92.11	-27.01			
71	3.24	0.95			
72	21.31	6.25			
73	-7.18	-2.11			
74	55.07	16.15			
75	-64.75	-18.99			
76	91.25	26.76			
77	20.41	5.99			
78	-9.15	-2.68			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULK HEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1960 TO 1963
TIME INTERVAL: 3.41 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-20.73	-6.08	79	111.98	32.84
55	-53.21	-15.60	80	85.97	25.21
56	-84.99	-24.92	81	91.81	26.92
57	-4.48	-1.31	82	99.21	29.09
58	-11.22	-3.29	83	55.66	16.32
59	-2.48	-0.73	84	54.41	15.96
60	31.87	9.35			
61	-17.43	-5.11			
62	-0.98	-0.29			
63	13.59	3.98			
64	-21.31	-5.96			
65	130.26	38.20			
66	121.00	35.49			
67	-24.06	-7.06			
68	26.13	7.66			
69	-10.33	-3.03			
70	-32.96	-9.67			
71	34.24	10.04			
72	86.20	25.28			
73	48.77	14.30			
74	81.42	23.88			
75	61.30	17.98			
76	90.30	26.48			
77	41.15	12.07			
78	65.26	19.14			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1963 TO 1966
TIME INTERVAL: 2.88 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	18.02	6.26	78	16.70	5.80
55	127.67	44.33	79	51.45	17.87
56	-7.62	-2.65	80	27.44	9.53
57	-52.97	-18.39	81	13.93	4.84
58	-70.88	-24.61	82	40.75	14.15
59	-14.18	-4.92	83	136.43	47.37
60	-60.32	-20.94	84	107.70	37.40
61	-88.15	-30.61			
62	31.61	10.97			
63	-19.53	-6.78			
64	6.72	2.33			
65	-19.45	-6.75			
66	-26.51	-9.21			
67	-70.73	-24.56			
68	-22.19	-7.70			
69	-58.32	-20.25			
70	32.77	11.38			
71	-14.29	-4.96			
72	-37.55	-13.04			
73	1.95	0.68			
74	-18.60	-6.46			
75	80.69	28.02			
76	-7.38	-2.56			
77	-15.20	-5.28			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1963 TO 1966
TIME INTERVAL: 2.88 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	2.81	0.98	79	22.17	7.69
55	10.25	3.56	80	-12.91	-4.48
56	72.71	25.25	81	9.59	3.33
57	-91.03	-31.61	82	-35.58	-12.35
58	4.73	1.64	83	34.59	12.01
59	-0.40	-0.14	84	7.50	2.60
60	10.01	3.48			
61	9.77	3.39			
62	50.09	17.39			
63	3.28	1.14			
64	8.64	3.00			
65	-68.52	-23.79			
66	23.55	8.18			
67	-6.35	-2.20			
68	-15.66	-5.44			
69	-24.18	-8.39			
70	15.06	5.23			
71	-25.44	-8.83			
72	3.46	1.20			
73	14.85	5.16			
74	-6.66	-2.31			
75	-4.72	-1.64			
76	-3.37	-1.17			
77	24.58	8.53			
78	-25.54	-8.87			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1966 TO 1969
TIME INTERVAL: 3.48 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-50.06	-14.38	79	0.40	0.12
55	-95.10	-27.33	80	-3.86	-1.11
56	-52.89	-15.20	81	18.76	5.39
57	-9.57	-2.75	82	50.43	14.49
58	-21.60	-6.21	83	-17.15	-4.93
59	-3.74	-1.07	84	-1.02	-0.29
60	28.10	8.08			
61	11.99	3.45			
62	-37.02	-10.64			
63	-6.74	-1.94			
64	-0.02	-0.01			
65	-54.85	-15.76			
66	-10.09	-2.90			
67	-29.44	-8.46			
68	-24.42	-7.02			
69	-24.90	-7.15			
70	8.18	2.35			
71	-30.54	-8.77			
72	10.53	3.02			
73	-38.85	-11.16			
74	7.28	2.09			
75	-45.85	-13.17			
76	-74.39	-21.38			
77	-10.93	-3.14			
78	-32.81	-9.43			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1966 TO 1969
TIME INTERVAL: 3.48 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-19.64	-5.64	79	-7.08	-2.03
55	-15.68	-4.50	80	-8.81	-2.53
56	-46.18	-13.27	81	8.47	2.43
57	27.53	7.91	82	-4.69	-1.35
58	-38.87	-11.17	83	-25.96	-7.46
59	-57.76	-16.60	84	-3.06	-0.88
60	-98.56	-28.32			
61	-61.89	-17.79			
62	-98.95	-28.44			
63	-25.99	-7.47			
64	-22.15	-6.36			
65	-45.50	-13.08			
66	-138.86	-39.90			
67	-28.54	-8.20			
68	-7.93	-2.28			
69	3.54	1.02			
70	7.58	2.18			
71	5.64	1.62			
72	12.76	3.67			
73	-38.77	-11.14			
74	-23.49	-6.75			
75	-52.75	-15.16			
76	-39.83	-11.45			
77	-55.00	-15.80			
78	21.71	6.24			

RATES OF CHANGE IN FEET PER YEAR FOR

THE HIGH WATERLINE

ISLAND BEACH STATE PARK

1969 TO 1971

TIME INTERVAL: 1.50 YEARS

NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.
54	47.01	31.34
55	66.44	44.29
56	48.23	32.15
57	79.67	53.11
58	86.35	57.57
59	28.03	18.68
60	30.01	20.01
61	-4.83	-3.22
62	27.99	18.66
63	-2.23	-1.49
64	-2.58	-1.72
65	46.90	31.27
66	54.09	36.06
67	31.85	21.23
68	93.83	62.56
69	56.59	37.73
70	48.08	32.05
71	28.11	18.74
72	27.19	18.12
73	41.97	27.98
74	20.79	13.86
75	88.50	59.00
76	88.19	58.79
77	53.38	35.59
78	63.64	42.42
79	54.79	36.53
80	22.05	14.70
81	21.58	14.39
82	28.06	18.71
83	72.38	48.25
84	96.67	64.44

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1969 TO 1971
TIME INTERVAL: 1.50 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	21.00	14.00	79	-9.70	-6.47
55	3.59	2.39	80	7.63	5.09
56	-54.01	36.01	81	-0.12	-0.08
57	-2.03	-1.35	82	-0.38	-0.25
58	9.45	6.30	83	-11.20	-7.47
59	3.88	2.59	84	-31.25	-20.83
60	48.90	32.60			
61	30.51	20.34			
62	13.10	8.73			
63	7.49	4.99			
64	16.22	10.81			
65	20.59	13.73			
66	20.40	13.60			
67	-13.76	-9.18			
68	10.03	6.69			
69	11.43	7.62			
70	-18.45	-12.30			
71	0.33	0.22			
72	-21.07	-14.05			
73	6.15	4.10			
74	-31.84	21.23			
75	20.04	13.36			
76	66.61	44.41			
77	66.61	44.40			
78	-44.30	-29.53			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1954 TO 1971
TIME INTERVAL: 16.92 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	6.08	0.36	78	29.64	1.75
55	-12.21	-0.72	79	39.92	2.36
56	-4.01	-0.24	80	68.09	4.02
57	-14.92	-0.88	81	37.65	2.22
58	21.85	1.29	82	127.60	7.54
59	-27.76	-1.64	83	198.40	11.73
60	-13.24	-0.78	84	173.97	10.28
61	-71.51	-4.23			
62	-2.82	-0.17			
63	-19.83	-1.17			
64	3.54	0.21			
65	-26.45	-1.56			
66	61.35	3.63			
67	-29.82	-1.76			
68	18.29	1.08			
69	52.36	3.09			
70	38.11	2.25			
71	1.13	0.07			
72	0.28	0.02			
73	13.91	0.82			
74	36.43	2.15			
75	39.54	2.34			
76	83.05	4.91			
77	49.29	2.91			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1954 TO 1971
TIME INTERVAL: 16.92 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	-2.82	-0.17	78	38.04	2.25
55	-8.32	-0.49	79	101.75	6.01
56	-36.14	-2.14	80	104.01	6.15
57	-8.10	-0.48	81	111.99	6.62
58	1.85	0.11	82	53.55	3.16
59	-20.58	-1.22	83	55.04	3.25
60	14.51	0.86	84	-23.41	-1.38
61	-47.62	-2.81			
62	-24.27	-1.43			
63	46.97	2.78			
64	17.24	1.02			
65	55.33	3.27			
66	50.10	2.96			
67	-35.20	-2.08			
68	-13.95	-0.82			
69	69.06	4.08			
70	29.42	1.74			
71	92.68	5.48			
72	94.56	5.59			
73	46.28	2.74			
74	85.27	5.04			
75	4.96	0.29			
76	163.16	9.64			
77	64.11	3.79			

RATES OF CHANGE IN FEET PER YEAR

THE HIGH WATERLINE

ISLAND BEACH STATE PARK

1960 TO 1961

TIME INTERVAL: 0.83 YEARS

NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
54	39.83	47.99	79	57.29	69.03
55	30.86	37.18	80	21.38	25.76
56	62.65	75.49	81	61.28	73.83
57	31.46	37.90	82	14.39	17.34
58	34.84	41.98	83	60.95	73.43
59	51.90	62.52	84	95.52	115.09
60	59.48	71.66			
61	5.51	6.64			
62	47.38	57.09			
63	15.95	19.22			
64	37.01	44.60			
65	90.82	109.42			
66	37.59	45.29			
67	29.32	35.32			
68	13.00	15.67			
69	28.00	33.73			
70	47.99	57.82			
71	63.65	76.68			
72	41.59	50.11			
73	27.11	32.66			
74	71.34	85.96			
75	40.14	48.36			
76	49.39	59.50			
77	35.84	43.18			
78	42.43	51.12			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1960 TO 1961
TIME INTERVAL: 0.83 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
54	-4.90	-5.90	79	12.70	15.30
55	12.79	15.41	80	-0.34	-0.40
56	-63.65	-76.69	81	9.99	12.04
57	-8.77	-10.56	82	4.16	5.01
58	3.89	4.69	83	-25.84	-31.13
59	-18.92	-22.80	84	1.18	1.42
60	-20.67	-24.90			
61	-38.37	-46.23			
62	-40.67	-49.00			
63	-37.02	-44.60			
64	-59.83	-72.09			
65	-3.03	-3.65			
66	-2.88	-3.47			
67	-67.53	-81.36			
68	-4.43	-5.33			
69	-58.75	-70.78			
70	-20.24	-24.38			
71	-39.77	-47.92			
72	2.71	3.27			
73	-35.77	-43.09			
74	-11.95	-14.40			
75	-6.85	-8.25			
76	-33.82	-40.75			
77	17.20	20.73			
78	6.46	7.78			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1961 TO 1962
TIME INTERVAL: 0.45 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
54	No Data	No Data	79	7.48	16.63
55	36.83	81.84	80	69.60	154.66
56	-10.47	-23.27	81	-7.05	-15.67
57	5.53	12.29	82	-3.23	-7.18
58	14.06	31.26	83	-25.81	-57.35
59	-32.25	-71.66	84	-16.63	-36.95
60	-11.34	-25.20			
61	-15.08	-33.51			
62	14.09	31.30			
63	-2.29	-5.08			
64	-7.13	-15.83			
65	-26.33	-58.50			
66	29.75	66.11			
67	-41.49	-92.20			
68	-12.46	-27.69			
69	8.92	19.82			
70	-23.82	-52.93			
71	-42.81	-95.12			
72	3.36	7.46			
73	-20.13	-44.74			
74	0.90	2.00			
75	44.93	99.84			
76	16.52	36.71			
77	61.31	136.25			
78	-10.66	-23.69			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD OR DUNE LINE
ISLAND BEACH STATE PARK
1961 TO 1962
TIME INTERVAL: 0.45 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Projected Rate/Yr.	Stations	Positional Change In Feet	Projected Rate/Yr.
54	No Data	No Data	79	242.67	539.26
55	-7.63	-16.95	80	153.67	341.48
56	-17.39	-38.64	81	96.01	213.35
57	34.01	75.58	82	85.25	189.44
58	22.92	50.93	83	100.63	223.61
59	27.37	60.82	84	60.54	134.53
60	72.01	160.02			
61	86.37	191.94			
62	54.92	122.03			
63	85.38	189.73			
64	64.84	144.09			
65	96.13	213.62			
66	97.81	217.36			
67	42.13	93.63			
68	23.66	52.58			
69	65.73	146.08			
70	41.07	91.28			
71	46.44	103.21			
72	116.20	258.22			
73	223.67	497.05			
74	60.54	197.77			
75	100.60	223.55			
76	127.37	283.05			
77	39.78	88.40			
78	105.91	235.36			

RATES OF CHANGE IN FEET PER YEAR FOR
THE HIGH WATERLINE
ISLAND BEACH STATE PARK
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	No Data	No Data	79	-92.53	-82.62
55	-141.03	-125.92	80	-108.37	-96.76
56	-25.90	-23.12	81	-47.30	-42.23
57	-17.35	-15.49	82	-30.37	-27.11
58	-6.75	-6.03	83	-95.56	-85.32
59	-40.06	-35.77	84	-99.10	-88.48
60	-33.97	-30.33			
61	46.20	41.25			
62	-99.04	-88.43			
63	19.16	17.11			
64	-55.82	-49.84			
65	-2.95	-2.63			
66	-47.58	-42.48			
67	57.40	51.25			
68	-10.37	-9.26			
69	48.07	42.92			
70	-63.13	-56.37			
71	26.91	24.02			
72	4.57	4.08			
73	26.63	23.77			
74	-15.86	-14.16			
75	-146.69	-130.97			
76	31.50	28.12			
77	-69.99	-62.49			
78	-9.35	-8.34			

RATES OF CHANGE IN FEET PER YEAR FOR
THE BULKHEAD AND DUNE LINE
ISLAND BEACH STATE PARK
1962 TO 1963
TIME INTERVAL: 1.12 YEARS
NEGATIVE VALUES INDICATE ACCRETION

Stations	Positional Change In Feet	Rate/Yr.	Stations	Positional Change In Feet	Rate/Yr.
54	No Data	No Data	79	160.78	143.55
55	8.91	7.96	80	87.05	-77.72
56	32.52	29.04	81	-20.25	-18.08
57	24.42	21.81	82	7.77	6.93
58	-6.15	-5.49	83	-20.30	-18.13
59	7.12	6.36	84	0.0	0.0
60	-7.94	-7.09			
61	-50.26	-44.88			
62	-1.17	-1.05			
63	-0.51	-0.46			
64	-1.31	-1.17			
65	42.28	37.75			
66	41.94	37.45			
67	16.82	15.02			
68	11.25	10.05			
69	21.64	19.32			
70	-9.76	-8.71			
71	63.12	56.36			
72	-12.89	-11.51			
73	-109.23	-97.53			
74	5.12	4.57			
75	-30.71	-27.42			
76	2.14	1.91			
77	-10.11	-9.03			
78	-21.21	-18.94			